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GRAND RIVER BASIN WATER MANAGEMENT STUDY TECHNICAL REPORT SERIES

EXISTING AND FUTURE WATER DEMAND FOR THE GRAND RIVER BASIN

TECHNICAL REPORT No. 26

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GRAND RIVER IMPLEMENTATION COMMITTEE

GRAND RIVER BASIN WATER MANAGEMENT STUDY

GRAND RIVER STUDY TEAM

TECHNICAL REPORT SERIES

REPORT #26

EXISTING AND FUTURE WATER DEMAND FOR THE GRAND RIVER BASIN

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ABSTRACT

This report is one of a series of technical documents prepared as part of the Grand River Basin Water Management Study for the Grand River Implementation Committee. It outlines existing and possible future water demand and identifies areas where future water shortages are probable.

Water demand is projected under four general categories: municipal, industrial, agricultural, and other (rural domestic, commercial and recreational). Projecting water demand is a challenging task because of the large number and variability of factors which may effect future change. Accordingly, a variety of analytical methods are used based on several scenarios for future urban and rural land use and population growth as outlined in Technical Report No. 8 Existing and Future Land Use Activities Within the Grand River Basin and Technical Report No. 12 Population Projections for Municipalities Within the Grand River Basin.

Water shortages are not expected in rural areas on the whole, although water storage for irrigating crops may be required in specific sub-basins if a drought extended over the summer months. In urban areas, water supply must be supplemented by new supplies in Kitchener, Waterloo, Cambridge and Guelph by the year 2001, if no conservation measures, or new pricing structures are implemented. The time at which new supplies would be required for these cities is dependent on population growth and water conservation practices. Two smaller communities, Fergus and Elora, may experience water shortages by the year 2031.

The information presented in this report provides a basis for the selection and timing of new supply projects. These projects form part of several overall water management plans investigated by the Basin Study and are outlined in associated technical reports. Questions with respect to this report should be directed to the Co-ordinator of the Grand River Basin Water Management Study, 400 Clyde Road, Box 729, Cambridge, Ontario.

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CONVERSTION FACTORS

1 acre = 0.4046856 hectares (ha)
1 inch = 25.4 millimetres (mm)
1 million gallons per day (mgd) = 4546 cubic metres per day (m^3/d)
1 gallon per day (gpd) = 4.546 litres per day (L/d)
1 gallon per capita per day (gpcd) = 4.546 litres per capita per day (L/capita·day)
1,000 gallons (gal) = 0.455 cubic metres (m^3)

1. INTRODUCTION

Extraction of surface and ground water for consumptive purposes within the Grand River basin can be classified under four general categories: municipal, industrial, agricultural, and other.

A municipal water supply system usually services residential, industrial, institutional, and commercial water consumers within an urban area, from a water distribution network linked to a common water source or sources. While most industries are linked to a municipal water supply system, there is a significant number of major industries particularly in the central basin, that obtain large quantities of water from private sources. Similarly, a significant amount of water is extracted from private sources for agricultural use such as irrigation and livestock consumption.

The "other" category refers to a limited number of commercial and recreational establishments which consume small quantities of water from private sources, usually on a seasonal basis.

The impact of water demand on available water resources in a particular area varies with the type of use and the extent of water sources. In the Grand River basin, the greatest stress is placed on water supplies in the central basin, particularly in the five major urban centres of Kitchener, Waterloo, Cambridge, Guelph and Brantford where water is consumed primarily for municipal and industrial uses.

Future growth in water demand within the basin may require additional water supplies in certain areas and will have a critical influence on the selection and timing of new supply projects. Hence, a detailed analysis of existing and possible future water demand was undertaken in order to identify areas where future water shortages are probable.

The succeeding chapters discuss existing and future water demand for the four categories identified above and indicate the location and extent of possible water shortages. Data are presented according to municipality and/or the sub-basin sectors outlined in Figure 1.1.

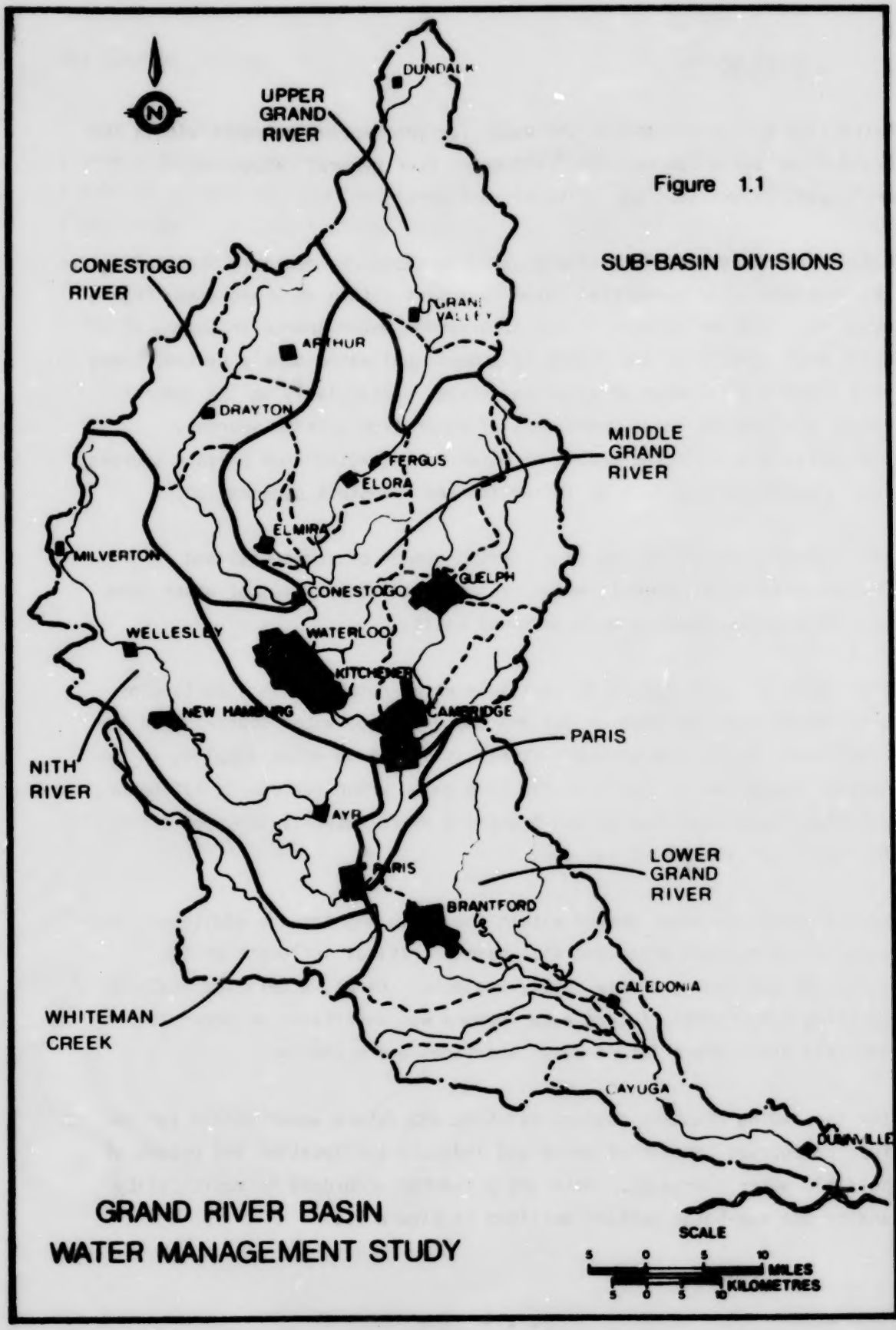


Figure 1.1

SUB-BASIN DIVISIONS

GRAND RIVER BASIN
WATER MANAGEMENT STUDY

2. MUNICIPAL WATER DEMAND

2.1 EXISTING WATER USE

Water taking permit records, available for the Grand River basin from the Ontario Ministry of the Environment, provide an estimate of the amount of ground and surface water allocated for consumptive purposes to municipalities. In 1978, 52.846 million gallons of water per day (mgd) (240 215 cubic metres per day (m^3/d)) were authorized for municipal use (Appendix A). This figure closely approximates the sum of the average daily consumption for all communities within the basin on a municipal water supply system (Table 2.1).

Within the basin, ground water is the primary source for municipal water supplies. In 1979, 19 communities extracted ground water for municipal supplies while 4 communities completed ground-water surveys in anticipation of future ground-water supply systems (Burford, Drayton, Grand Valley and Salem). By contrast, only 3 communities utilized surface water sources for municipal supplies (Brantford, Cayuga and Dunnville). A summary of water use statistics for these communities is outlined in Table 2.1.

Statistics indicate that approximately 81% of the total population of the basin uses water supplied by municipal systems. The remaining population (approximately 105,000) is supplied by private water sources, primarily wells. Four cities: Kitchener, Waterloo, Cambridge, and Guelph place the most stress on ground water. Although the City of Brantford exhibits high consumption rates, little stress is placed on water supply since water is extracted directly from the Grand River.

Water consumption in the major urban centres by user class and by season is outlined in Table 2.2. Because of the extensive information base required, these data were collected for only one year, 1978 (Appendix B). In addition, further research was undertaken to describe the primary demographic and economic factors which influence municipal water demand: pricing systems for water sales (Table 2.3); employment characteristics (Table 2.4); and residential land use and demographic characteristics (Table 2.5).

TABLE 2.1

Summary of Municipal Water Use Characteristics for the Grand River Basin

Community	Serviced Population 1976	Average Daily Consumption (mgd) 1977	Maximum Daily Consumption (mgd) 1977	Per Capita Consumption (gpd)[1] 1976-1977	System Capacity (mgd)[2] 1979	Source of Water Supply[2] 1979
Arthur	1,628	0.200	0.390	123	0.633	6 wells
Ayr	1,331	0.110	N/A	83	1.037	2 wells
Baden	4,300	0.409	0.649	95	1.382	2 wells
New Hamburg					.302	2 wells
Caledonia	3,774	0.323	0.645	86	2.560	5 wells
Cambridge	72,950	8.577	12.866	118	16.990	25 wells
Dundalk	1,130	0.113	0.201	100	0.432	3 wells
Elmira	8,095	1.680	2.810	208	4.460	6 wells
St. Jacobs					0.150	2 wells
Elora	2,425	0.247	0.355	102	0.668	2 wells
Fergus	5,967	0.615	0.900	103	1.764	5 wells
Guelph	71,349	9.500	13.100	133	25.81 (winter)	27 wells
					28.81 (summer)	Arkell Springs
Kitchener	133,815	18.177	29.084	98	22.242	29 wells
Waterloo	51,473				8.774	12 wells
					1.632	2 infiltration wells (Kitchener-Waterloo)
Maryhill	150	0.008	N/A	53	0.072	2 wells
Milverton	1,402	0.129	N/A	92	0.315	2 wells
Paris	6,993	1.060	1.630	152	2.880	2 wells
Plattsville	N/A	N/A	N/A	N/A	0.374	2 wells
Rockwood	N/A	N/A	N/A	56	0.864	2 wells
St. George	1,000	0.150	0.230	150	1.800	1 well
Brantford	69,091	9.670	16.120	140	17.500	Grand River
Cayuga	1,154	0.150	0.240	130	0.240	Grand River
Dunnville	5,553	N/A	N/A	N/A	3.200	Lake Erie

N/A - Not Available

[1]Note: Per capita consumption rates were estimated by dividing the 1976 serviced population into the 1977 average daily consumption rates.

[2]Source: Sibul, Walmsley and Szudy (1980).

TABLE 2.2

Water Consumption Characteristics for Major Urban Centres, 1978

CITY	WATERLOO	KITCHENER	GUELPH	BRANTFORD	CAMBRIDGE	AVERAGE
ANNUAL CONSUMPTION BREAKDOWN (%)						
Residential	31	26	25	26	27	26
Industrial	20	36	25	40	26	30
Apartment	10	12	9	6	7	9
Institutional	15	6	13	4	5	10
Commercial	12	10	5	4	15	9
Unaccounted	12	10	23	20	20	19
TOTAL	100	100	100	100	100	
TOTAL gpcd	99	103	131	143	115	119
AVERAGE SUMMER DAY ÷ AVERAGE WINTER DAY	1.12	1.17	1.15	1.28	1.12	1.17
MAXIMUM DAY ÷ AVERAGE DAY	1.65	1.55	1.70	1.61	1.54	1.62
RESIDENTIAL CONSUMPTION (gpd/METER)						
Average annual	133	126	159	135	124	133
Average winter	122	106	118	81	112	105
Average summer	166	176	189	183	155	171
Maximum day	381	362	479	419	321	392

TABLE 2.3

Water Rates for Major Urban Centres, 1978

CITY	WATERLOO	KITCHENER	GUELPH	CAMBRIDGE	BRANTFORD
TYPE OF RATE STRUCTURE	FLAT UNIT RATE	DECLINING BLOCK	DECLINING BLOCK	DECLINING BLOCK	DECLINING BLOCK
Block 1					
size (gal)	0	0-3,115	0-50,000	0-75,000	0-44,000
rate/1,000 gal	$.53	$.85	$.55	$.63	$.55
Block 2					
size (gal)	N/A	3,116-105,910	50,001-300,000	>75,000	44,001-374,000
rate/1,000 gal		$.71	$.45	$.51	$.42
Block 3					
size (gal)	N/A	105,911-186,900	300,001-12,000,000	N/A	>374,000
rate/1,000 gal		$.64	$.35		$.33
Block 4					
size (gal)	N/A	>186,900	>12,000,000	N/A	N/A
rate/1,000 gal		$.59	$.25		
Sewer Surcharge	100% of consumption charge	75% of total water bill	70% of total water bill	70% of total water bill	fixed rate for small meter, 85% of total water bill for large meters

N/A - Not applicable

TABLE 2.4

Industrial Profiles for Major Urban Centres, 1978

CITY	WATERLOO	KITCHENER	GUELPH	CAMBRIDGE	BRANTFORD
% OF POPULATION WORKING IN INDUSTRY	16	20	16	28	26
% INDUSTRIAL EMPLOYEES BY INDUSTRY TYPE					
Food and Beverage	7	18	4	3	4
Tobacco Products	--	--	8	--	--
Rubber and Elastic Products	9	9	3	3	6
Leather Products	2	13	--	7	--
Textiles	7	4	2	10	2
Clothing	1	6	5	1	5
Wood	5	1	1	1	2
Furniture and Fixtures	9	1	1	2	2
Paper and Allied Products[1]	1	1	2	--	5
Printing and Publishing	2	3	2	1	3
Primary Metals[1]	1	1	8	4	7
Machinery	8	7	15	18	33
Metal Fabricating	13	10	12	20	8
Transport Equipment	--	10	2	7	5
Electrical Products	37	8	25	11	8
Non-metallic Mineral Products	--	2	2	1	6
Chemicals and Chemical Products[1]	2	2	7	7	4
Miscellaneous	1	1	1	2	3

[1]These industries are the largest water users.

Source: Williams and Veale (1980).

TABLE 2.5

Demographic and Land Use Characteristics for Major Urban Centres

CITY	WATERLOO	KITCHENER	GUELPH	CAMBRIDGE	BRANTFORD
Serviced Population[1]	51,473	133,815	71,349	69,091	72,950
Total Serviced Dwelling Units[1]	16,993	43,806	23,048	25,119	23,988
Persons per Dwelling Unit[1]	3.03	3.05	2.10	2.75	3.04
% Apartment Units[2]	34	34	30	24	21
% Attached Units[2]	11	11	12	13	9
% Semi-detached Units[2]	5	5	3	6	8
% Detached Units[2]	51	51	55	57	61
Residential Acreage[3] (1976)	2,174	5,894	4,020	4,867	4,901

[1]Source: Appendix B, Table B1.1.

[2]Source: Canada Census, 1976 (catalogue 92-810).

[3]Source: Veale (1980 a).

2.2 FUTURE WATER DEMAND

The stress on ground-water supplies is expected to increase as urban growth continues. Table 2.6 outlines the projected low, medium and high populations for each municipality located wholly or partly within the basin (Technical Report No. 12; and Veale, 1980 b). An additional "low low" projection was generated for the Cities of Kitchener, Waterloo and Cambridge as follows:

Projected Population

"Low Low"

	2001	2031
Kitchener	186,369	221,757
Waterloo	69,838	83,060
Cambridge	111,533	132,699
Total	367,740	437,516

According to these estimates, the combined population of the Cities of Kitchener, Waterloo, Cambridge and Guelph could range between 458,000 and 587,500 by the year 2001, and 559,000 and 998,500 by the year 2031.

The following sections describe the methodologies used to predict water needs for basin municipalities and detail estimates of future municipal water demand. The implications of these analyses on water management are also discussed.

2.2.1 Major Urban Centres

Three basic approaches were used in projecting future municipal water demand for the Cities of Kitchener, Waterloo, Cambridge, Guelph and Brantford. Demand was predicted by assuming that: (1) existing water consumption rates remain the same in the future (base case projection), (2)

TABLE 2.6

Population Projections by Municipality for the Grand River Watershed

Municipality	Population (1976)	Low Projection (2001)	Medium Projection (2001)	High Projection (2001)	Low Projection (2031)	Medium Projection (2031)	High Projection (2031)
Halton Region	2,381	2,697	3,053	3,906	3,131	4,115	7,074
Town of Milton	1,705	1,931	2,186	2,797	2,243	2,947	5,066
Town of Halton Hills	676	766	867	1,109	889	1,168	2,008
Haldimand-Norfolk Region	17,776	24,329	27,514	31,628	33,074	38,848	45,975
Town of Haldimand	8,961	13,596	16,367	19,739	19,504	23,494	28,316
Caledonia	3,669	6,500	9,750	13,000	13,000	15,825	18,649
Cayuga	1,143	1,200	1,850	2,500	2,500	3,043	3,586
Town of Dunnville	5,969	7,815	7,923	8,458	10,563	11,580	13,366
City of Nanticoke	2,846	2,918	3,224	3,431	3,007	3,774	4,293
Hamilton-Wentworth Region	11,279	11,993	12,775	14,420	12,912	14,788	19,372
Town of Ancaster	3,268	3,478	3,701	4,191	3,749	4,299	5,649
Township of Flamborough	7,710	8,206	8,734	9,888	8,845	10,144	13,327
Township of Glanbrook	301	309	320	341	318	345	396
Waterloo Region	291,164	459,900	490,057	509,942	506,000	703,392	809,034
City of Kitchener	131,801	208,795	222,486	231,514	229,724	319,340	367,301
City of Cambridge	71,482	116,815	124,474	129,525	128,524	178,662	205,495
City of Waterloo	49,972	86,461	92,131	95,869	95,128	132,237	152,098
Township of Wellesley	6,404	8,738	9,311	9,689	9,614	13,364	15,372
Village of Wellesley	842	1,461	1,557	1,620	1,608	2,235	2,571
Township of Wilmot	10,566	13,337	14,212	14,788	14,674	20,398	23,462
Village of New Hamburg	3,628	4,535	4,832	5,028	4,989	6,935	7,977
Township of Woolwich	16,038	19,776	21,072	21,928	21,758	30,246	34,788
Town of Elmira	7,034	8,701	9,272	9,648	9,574	13,308	15,307
Township of North Dumfries	4,901	5,979	6,370	6,629	6,578	9,144	10,517
Village of Ayr	1,331	2,143	2,283	2,376	2,357	3,277	3,769
Brant County	96,144	117,616	130,155	144,293	149,964	187,890	235,489
*City of Brantford	69,930	89,680	99,239	109,772	120,875	151,045	188,575
Town of Paris	6,691	8,000	8,800	9,484	8,609	10,921	13,168
Township of Brantford	6,161	6,558	6,979	7,901	7,068	8,106	10,649
Township of Burford	2,899	2,826	3,284	3,718	2,735	3,814	5,011
Township of Oakland	1,291	1,258	1,462	1,656	1,218	1,698	2,232
Township of Onondaga	1,368	1,333	1,550	1,754	1,291	2,039	2,365
Township of Tuscarora (Indian Reserve)	3,853	3,756	4,365	4,941	3,635	5,069	6,660
Township of South Dumfries	3,951	4,205	4,476	5,067	4,533	5,198	6,829

Population Projections by Municipality for the Grand River Watershed

Municipality	Population (1976)	Low Projection (2001)	Medium Projection (2001)	High Projection (2001)	Low Projection (2031)	Medium Projection (2031)	High Projection (2031)
Dufferin County	6,240	7,996	11,469	14,628	10,839	20,392	32,107
Village of Grand Valley	1,060	1,532	1,739	2,132	2,383	3,150	4,931
Township of Amaranth	1,875	2,405	3,831	4,874	3,241	6,939	11,831
Township of East Garafraxa	1,234	1,583	2,584	3,208	2,133	4,681	7,786
Township of East Luther	866	1,111	1,770	2,666	1,497	3,540	4,826
Township of Malancthon	1,205	1,365	1,545	1,748	1,585	2,082	2,733
Grey County	1,312	1,748	2,048	2,300	2,430	3,559	4,633
Village of Dundalk	1,130	1,561	1,854	2,094	2,238	3,350	4,394
Township of Proton	182	187	194	206	192	209	239
Oxford County	8,030	9,095	10,298	11,651	10,564	13,880	18,212
Township of East Zorra-Tavistock	796	901	1,021	1,155	1,047	1,376	1,805
Township of Blandford-Blenheim	5,959	6,750	7,642	8,646	7,840	10,300	13,515
Township of Norwich	1,275	1,444	1,635	1,850	1,677	2,204	2,892
Perth County	4,620	5,197	6,054	7,155	5,988	8,403	12,450
Village of Milverton	701	758	1,029	1,468	832	1,629	3,563
Township of Wallace and Elma	88	100	113	128	116	152	199
Township of Ellice, North and South Easthope	1,625	1,840	2,083	2,358	2,138	2,809	3,685
Township of Mornington	2,206	2,499	2,829	3,201	2,902	3,813	5,003
Wellington County	108,840	138,286	173,477	199,120	184,007	307,342	416,148
City of Guelph	70,374	90,250	115,456	130,469	121,643	209,133	273,669
Town of Fergus	5,967	8,505	11,133	13,187	11,577	22,810	32,009
Village of Arthur	1,628	2,038	2,200	2,362	2,530	3,111	3,692
*Village of Elora	2,974	4,588	5,355	6,227	7,722	10,844	15,114
Village of Drayton	813	1,042	1,179	1,507	1,405	1,843	3,162
Township of Arthur	622	638	662	705	657	714	818
Township of Eramosa	4,084	5,237	6,700	8,145	7,059	12,137	18,651
Township of Erin	2,745	3,520	4,503	5,475	4,745	8,157	12,536
Township of West Garafraxa	2,215	2,509	2,841	3,214	2,914	3,829	5,023
Township of Guelph	2,862	3,670	4,695	5,708	4,947	8,505	13,070
Township of West Luther	816	636	837	869	367	862	936
Township of Maryborough	2,025	2,156	2,294	2,597	2,323	2,664	3,500
Township of Peel	3,837	4,084	4,347	4,921	4,402	5,048	6,632
Township of Nichol	2,766	3,133	3,547	4,538	3,639	4,781	8,220
Township of Pilkington	1,840	2,084	2,360	2,670	2,421	3,180	4,173
Township of Puslinch	3,272	4,196	5,368	6,526	5,636	9,724	14,943
TOTAL	547,786	778,857	866,880	939,043	918,909	1,302,609	1,600,444

* With Annexation

new conservation methods are implemented, and (3) the water rate structure is modified to reflect changing water prices. Details of the methodologies used for prediction are outlined below.

(1) Base Case Projections

To determine future municipal water demand using the base case projection, the following methodology was used. It was assumed that the 1978 per capita rates for non-domestic user classes would remain the same in the future. For industrial consumption, this implies that the industrial profile in each municipality will remain unchanged in the future and that the industrial labour force will grow at the same rate as the total population.

To project residential water demand, water consumption was separated into two components: in-house consumption for dwelling units, and summer consumption for lawn watering.

To estimate a range in the number of dwelling units which may be necessary in the future for each urban area, the projected low, medium and high populations for the years 2001 and 2031 were divided by the anticipated future family sizes. Future family sizes are expected to decline from an average of 3.1 in the year 1976 to 2.6 in the year 2001 and remain at a stable size thereafter for the five major centres (Veale, 1980 c). The rate of consumption for apartment units and the in-house consumption rate for non-apartment dwelling units were assumed to remain at the 1978 level.

Since the volume of summer lawn sprinkling for an individual household varies with lawn size, an investigation of trends in housing and lot sizes was undertaken for the five major urban centres in order to estimate the number of non-apartment units which could be expected in the future and the average lawn sizes associated with these dwelling units (Veale, 1980 c). Results of the study revealed that it is probably reasonable to assume constant densities of 7 and 12 units per acre for semi-detached and attached (row house) units in the future. However, it is expected that the density of detached units will increase from the current level of 4.5 units

per acre to 5.6 units per acre after 1991. To predict the future mix of dwelling unit types, further analysis was carried out. The methodology used is summarized in Appendix C. The results of the study are outlined in Table 2.7.

From these data, the total number of non-apartment dwelling units was estimated and the area of lawn at the expected future density was determined for the years 2001 and 2031. Future water demand for lawn sprinkling was estimated using an observed per acre sprinkling rate (Appendix B1.2).

Following the above methodology, a drastic shift in the profile of dwelling unit types is forecast. However, current trends suggest that a drastic shift may not occur. Therefore, the base case projection was also estimated using existing proportions of dwelling types to the year 2031. These two approaches, with and without changes in the mix of housing types provide a test of water demand sensitivity to housing characteristics.

In order to estimate total pumpage, system losses must be added to total metered pumpage. For the base case projection, system losses were assumed to be a constant percentage of total pumpage. This percentage was based on 1978 losses. The volume of losses varies with metered pumpage from summer to winter because of this assumption. Seasonal variations in metered pumpage were assumed to be caused entirely by residential sprinkling demand. This assumption is supported by the analysis of seasonal non-residential and non-domestic consumption discussed in Appendix B.

(2) Water Demand Projections Based on the Implementation of Conservation Measures

Water conservation programs can comprise a diverse range of actions that aim at reducing average day or maximum day demand; actions that can affect the flow of water at any point from the source of supply through to the end use. Water conservation programs may include leakage surveys, reductions in system pressure, metering, prohibitive pricing, building code changes, restrictions on non-essential uses, education programs and incentive

TABLE 2.7

Estimation of Future Mix of Housing Types in the Major Urban Centres

Community	Kitchener/Waterloo				Cambridge				Guelph			Brantford		
Population Forecast	Low Low	Low	Med	High	Low Low	Low	Med	High	Low	Med	High	Low	Med	High
% of Detached Units														
1976	51	51	51	51	57	57	57	57	55	55	55	61	61	61
2001	35	34	34	33	39	39	39	38	39	38	38	44	44	43
2031	34	33	31	31	38	38	37	37	38	36	34	43	42	41
% Apartments														
1976	34	34	34	34	24	24	24	24	30	30	30	21	21	21
2001	47	47	48	48	36	36	36	36	41	42	42	33	33	33
2031	47	48	50	51	36	36	38	38	42	44	46	34	35	36
% Semi-Detached														
1976	5	5	5	5	6	6	6	6	3	3	3	8	8	8
2001	11	11	11	11	15	15	15	15	11	11	11	16	16	16
2031	11	11	11	10	15	15	14	14	11	10	10	16	16	16
% Attached Units														
1976	11	11	11	11	13	13	13	13	12	12	12	9	9	9
2001	8	8	8	8	11	11	11	11	9	9	9	7	7	7
2031	8	8	8	8	11	11	11	11	9	10	10	7	7	8

programs to promote and even subsidize conservation efforts. Consumers may respond to these actions by being more conscientious about their rate of water consumption (turning off taps, fixing leaks, less lawn watering, etc.) or by investing in water conserving equipment (commercial and industrial recycling, flow reducers in taps, showers and toilets, improved appliances, etc.).

For the purpose of this study, actual and hypothetical case studies have been reviewed in order to identify savings anticipated with a water conservation program (Tables 2.8 and 2.9). With this type of analysis, double counting of the impacts of various conservation actions must be avoided. For instance, a particular program might use both higher prices and plumbing code amendments to reduce average day demand. If either action, by itself generates a 5% reduction in demand, it is unlikely that the combined effect would be 10%, since part of the response to higher prices could involve investment in the newly-sanctioned water-conserving fixtures. Evidence from observed case studies is valuable in this respect since it captures the overall observed response of community demand to combined action in a water conservation program.

New pricing policies may be one component of a water conservation program. A new policy, to be effective, must incorporate higher rates for water since only an increase in price will discourage consumption. An overall rate increase will affect all consumers. Selective rate increases brought about by modifications of the rate structure will influence only certain consumer groups or components of demand like summer lawn sprinkling.

Several hypothetical case studies suggest that average day demand can be cut by up to 12% just by modification of the domestic demand component, with the most frequent prediction of savings lying between 4% and 7%. Greatest in-house savings come from a reduction in water used for toilet flushing. The analysis of sprinkling demand summarized in Table 2.10, suggests that metering has the greatest impact. Other actions listed here give rise to a savings of 3% to 10% and are of greatest interest in this study since metering is already used in the Grand River basin. A 5% to 10% reduction in maximum day demand due to reduced sprinkling use combined with

TABLE 2.8
Water Conservation Case Studies - Actual Programs

Community	Washington	Dallas, Texas	Elmhurst, Illinois	Fairfax Co., Virginia	Westminister, Colorado	Gettysburg & Springettsburg
% Reduction of Flow:						
(a) Average Day	14 (residential)	4	15	5	7.5	10
(b) Maximum Day	N/A	12	N/A	18	N/A	N/A
(c) Loading Factor (b)/(a)	N/A	8	N/A	15	N/A	N/A
(d) Sewage Flow	N/A	N/A	10	N/A	N/A	N/A
Program Description:						
(a) Pricing Policies	X (increasing block)	X (flat rate & (excess use charge)	X (excess use charge)	X (flat rate & excess use charge)	X (increasing block)	
(b) Education	X	X	X	X		X
(c) New Plumbing code	X		X	X		X
(d) Incentive Programs (retro fitting, other)			X		X	X
Reference:	McGarry and Brusnigam (1978)	Rice and Shaw (1978)	Meyer et al (1978)	Griffith (n.d.)	McGhee; Reardon; and Shulman (1978)	Sharpe (1979)

N/A - Not available

TABLE 2.9

Water Conservation Case Studies - Hypothetical Domestic Demand Programs

Author	Sharpe (1978) (1)	Sharpe (1978) (2)	Sharpe (1978) (3)	North Marine County (1976) (1)	North Marine County (1976) (2)	Stone (1978)	Water Conservation Centre (1978) (1)	Water Conservation Centre (1978) (2)	Water Conservation Centre (1978) (3)
% Reduction of Flow:									
(a) In-house consumption	30	39	12-39	19	35	19-35	31	37	49-62
(b) Domestic sewage	50	0	30-100	20	30	10-18	38	38	63-100
(c) Total average day consumption[1]	6	8	2-8	4	7	4-7	6	7	10-12
Conservation Methods:									
(a) Change consumption habits (without devices, etc.)				X				X	X
(b) Retro fit:									
toilets	X			X	X	X	X	X	
taps	X						X	X	X
showers	X			X	X	X	X	X	X
(c) New toilet			X		X				X
(d) New appliances					X	X			
(e) Recycling waste water		X							

[1]Assumes that in-house demand is 20% of total pumpage and that only in-house demand changes. 20% is used on the basis of information in Appendix B.

a 20% to 37% reduction in in-house domestic use (assumed to be 20% of maximum day demand) would yield an overall reduction of 9% to 17% in maximum day demand. The upper limit, based on a 62% reduction in in-house use would be a 22% reduction of maximum day demands. This discussion of data generated by hypothetical studies is summarized in Table 2.11.

The success of a water conservation program can be measured by comparing potential savings to those that are realized. From the actual case studies in Table 2.8, it is apparent that a 5% to 10% reduction in average day demand and a 10% to 20% reduction in maximum day demand can be realistically expected from a water conservation program implemented in an existing community. These savings seem to compare very favourably to savings indicated in Table 2.9 until one recalls that these actual savings come from all consumer classes and not just residential customers. Suppose residential customers contributed to a conservation effort in proportion to their share of total demand, while other customers made up the remaining contribution. A 10% drop in total demand would imply a 10% drop in residential demand. However, hypothetical residential savings range between 12% and 62%. Viewed in this light, existing water conservation programs have met with only moderate success if potential savings are the criteria for success. Of course, in new subdivisions, the chance of increasing savings is greater because of the relative ease of installing water saving fixtures during construction and no retro-fitting is required.

For water conservation demand projections, two different assumptions are made about domestic demand. The first entails a 10% reduction of in-house use and a 15% reduction of sprinkling use for all home owners; this reflects the observed experience with a low response from home owners. The second projection assumes a 29% reduction of existing in-house use; a 40% reduction of new in-house use and a 19% reduction of sprinkling demand; this reflects the potential conservation case with a high response from home owners.

Very little information on water conservation by non-residential users is available. For this reason a crude procedure was used to project the impact of water conservation efforts on this component. It was assumed

TABLE 2.10

Water Conservation Case Studies -
Hypothetical Sprinkling Demand Programs

Device Description	Percentage Reduction in Maximum Day Demand	
	Mean	Range
Meters (pricing)	40	25 - 58
Pressure regulation	5	0 - 27
Flow restriction	5	0 - 20
Voluntary hose meters	3	2 - 4
Mandatory hose meters	10	5 - 15
Soil moisture sensors	10	0 - 20

Source: Stone (1978)
Water Conservation Centre (1978)

TABLE 2.11

Potential Impacts of Residential Savings
In A Water Conservation Program
(All Savings Attributed to Residential Demand Only)

Percentage Reduction	Likely Range	Upper Limit
Average Day Demand:		
In-house[1] (20% of total)	20 to 37	62
Total	4 to 7	12
Maximum Day Demand:		
In-house[1] (12% of total)	20 to 37	62
Sprinkling[1] (40% of total)	13 to 25	25
Total	9 to 17	22

[1]Percent shares of each component in Total demand are based on values in Appendix B.

that water consumption rates among non-residential users with the exception of industries would remain constant while per capita industrial consumption was adjusted downward to project new industrial needs. This adjustment reflects an assumption that future industrial growth will occur only in industries that use moderate amounts of water (no paper, chemical, petroleum or primary metal products). Such an assumption would be justified if cities were reluctant to attract water intensive manufacturers into their communities (Appendix B1.3).

The final component of pumpage to be considered in the water-conservation demand projection is the system loss or unaccounted pumpage. System losses include leakage, fire fighting consumption and unmetered consumption. Leakage is generally the principal component of water losses (Keller, 1976). An engineering study would be required to accurately describe existing system losses and potential savings. Such a study was not feasible. Instead, a statistical analysis of losses for Ontario communities with populations in excess of 10,000 was used to characterize losses. The data base for the analysis came from results of a 1977 survey undertaken for the publication, National Inventory of Municipal Waterworks and Wastewater Systems in Canada, 1977 (Canada Supply and Services, 1978). Results of the analysis are as follows:

Sample size	= 50
Median % loss	= 19
Mean % loss	= 11
Modal % loss	= 5
Standard deviation	= 8
Maximum % loss	= 39
Minimum % loss	= 1

Cell distribution:

Range	Count
% loss <5	= 4
5 < % loss <10	= 20 (14 at 5%)
10 < % loss <15	= 13 (8 at 10%)
15 < % loss	= 10 (6 at 15%)

Cities within the Grand River basin experienced an average loss of 19% in 1978 (Appendix B), 8 points above the provincial average. In light of the provincial statistics, it seemed reasonable to assume that new pumpage would include a loss component equal to 10% of total pumpage. Losses for existing pumpages were assumed to be constant, since, for existing systems, leak detection and repair is difficult and costly.

(3) Water Demand Projections Based on Changing Water Prices

Water prices may change for two reasons: prices may be altered if new water rate structures are adopted, and prices will likely increase as costly new sources of supply are developed. Numerous studies have investigated the impact of price on water demand. The more rigorous and exhaustive studies have generally discovered a significant negative relationship; ie. as price increases demand per customer falls (Danielson, 1979; DeRooy, 1974; Grebenstern and Field, 1979; Grima, 1972; Howe and Linaweaver, 1967). For this reason, water demand projections that allow demand to respond to price changes were made.

A variety of rate structures can be adopted by municipalities. In 1980, Kitchener, Cambridge, Guelph and Brantford used a declining block rate price structure, while Waterloo charged a flat rate for water. The impact of four alternative rate structures on water consumption was also investigated for projection purposes. A description of the rate structures considered is outlined below.

1. Declining block rate - successive blocks of consumption are charged progressively lower prices. Generally the first block includes residential and small commercial consumption, the second commercial and light industrial, and the third and fourth heavy industrial use (there may, of course, be fewer or more blocks than four)

2. Flat rate - all consumption is priced at the same unit rate

3. Increasing block rate - similar to a declining block rate except that prices increase for successive blocks

4. Seasonal surcharge - flat rates apply with a surcharge levied against all summer use

5. Excess use rate - flat rate applies with a surcharge levied against any summer consumption in excess of some multiple of the average winter consumption

The merits of these various rate structures are discussed by Phillips (1977) and others (Griffith, 1977; Goolsby, 1975; Grima, 1972, Hanke and Davis, 1973; Holtz and Sebastian, 1978).

For each city, prices for the alternative rates were selected after examining capital and operating costs and consumption levels for 1978. The flat rate was estimated as a total average unit cost in 1978. The base rate for the two schemes using seasonally varied prices was estimated as a net average unit cost in 1978 (net of capital costs) in keeping with recommendations from the literature on peak-load pricing (Goolsby, 1975). Prices for the increasing block rate structure resembled existing prices for the declining block rate structures in range and overall level. New prices, selected as described above, were adjusted iteratively to satisfy the condition that the resulting revenue from water sales be within 5% of revenues obtained from observed sales in 1978. This condition on revenue applied only to revenue from the unit charge on water sales. Service charges were not included but sewerage surcharges were included if they were a component of the unit charge for water. This constraint was imposed in order to show how water utilities could modify water consumption characteristics via pricing while maintaining the same income level.

The mathematical expression used to relate price to consumption is called a demand curve. A parameter of demand curves that measures the sensitivity of consumption to price is called the price elasticity of demand. It is the ratio of the percentage change in consumption to the related percentage change in price. Demand curves are derived using a statistical analysis of

information describing the economic behaviour of consumers. For water demand, this entails an analysis of observed consumption rates and associated water prices along with other variables that influence consumption.

Many estimates of water demand curves are available. Some of these consider total community consumption (Macerollo and Ingram, 1979) while others consider only industrial consumers (DeRooy, 1974; Grebenstern, 1979) or residential consumers (Grima, 1972; Howe and Linaweaver, 1967; Howe, 1968; Kitchen, 1975). A critical factor to be considered in water demand forecasts is the impact of demand on capacity requirements. Since capacity needs are determined by maximum day demands, it was necessary to select estimates of demand curves that could be used to analyse maximum day demand.

Studies by Linaweaver and Howe (1967) and by Howe (1968) provide demand curves for residential consumption that measure average winter day use, average summer day use and maximum summer day use.

These curves provide an excellent base of data combining cross-section and time-series information. A comparable study was undertaken by Grima (1972) for southern Ontario using cross-section data only. The resultant demand curves displayed a considerably greater sensitivity of consumption to price than those predicted by Howe and Linaweaver. In fact, Grima's demand curves predicted that average summer day demand would fall below average winter day demand for certain Grand River communities when a high summer price was levied. This result did not seem credible in light of the price changes being considered. Accordingly, the Howe and Linaweaver demand curves were adopted for this study. The price elasticities of demand from these studies are compared in Table 2.12.

Little work has been done on demand curves for industrial users. From a review of two studies (DeRooy, 1974; Grebenstern, 1979), an elasticity of -.3 was chosen to characterize industrial demand. This was considered a conservative estimate. Commercial and institutional consumers and apartment dwellers were assumed to be insensitive to price changes.

TABLE 2.12

Price Elasticities of Demand for Residential Water Consumption

Author	Grima (1972)	Howe & Linaweaver (1967) and Howe (1968)
Average Summer Day Demand		
(a) Elasticity	-1.071	-.931
(b) % change in Consumption for a 25% price increase	-27%	-23%
Average Winter Day Demand		
(a) Elasticity	-.751	-.214
(b) % change in consumption for a 25% price increase	-19%	-5%
Maximum Day Demand		
(a) Elasticity	N/A	-.671
(b) % change in consumption for a 25% price increase	N/A	-17%

N/A - Not available

The analysis of water rate structures was not carried into the future. Rather, information about the influence of rate structures in 1978 was used as a check of the forecast previously discussed which considered water conservation measures. However, one aspect of this work was useful in forecasting the impact of higher cost sources of supply on consumption. For simplicity sake, a flat rate price structure was assumed in this part of the price analysis. The starting prices used in the first time period (1976-1980) was the flat rate price derived for the rate structure analysis.

An analysis of how total and per capita demand will behave as higher cost sources of water supply are brought on line was also investigated. To predict the impact of these new supplies on price, the source of supply costs, both operating and capital, for existing systems were identified. Annual capital costs were measured by amortizing estimated asset values over a 20 year period using a 10% interest rate. Total annual supply costs were divided by pumpage to derive an estimate of existing supply costs per 1,000 gallons (.455 m^3).

Annual unit operating and capital costs for new supply systems were estimated by assuming that the average pumpage rates for new surface water systems would be 50% of the design capacity while pumpage rates for ground-water systems would be 75% of the developed aquifer capacity. The difference between existing and new unit supply costs was added to the initial flat rate price when development of a new source was necessary. This method of adjusting price is consistent with marginal costs pricing, a pricing philosophy discussed by Hanke and Davis (1973) and others (Holtz and Sebastian, 1978; Goolsby, 1975; Grima, 1972).

2.2.1.1 Water Demand Projections for the Cities of Kitchener and Waterloo

Since the cities of Kitchener and Waterloo display many similar water use characteristics and have a recent history of potential and actual water shortages, they are discussed together. The water shortages experienced by the two cities prompted them to implement a water conservation program

which included water use education and restrictions on lawn sprinkling. The low per capita rates for 1978 in these two communities may testify to the success of the program. Concurrently, the decrease in water use made in response to the shortages must be taken into account in the interpretation of the following projections.

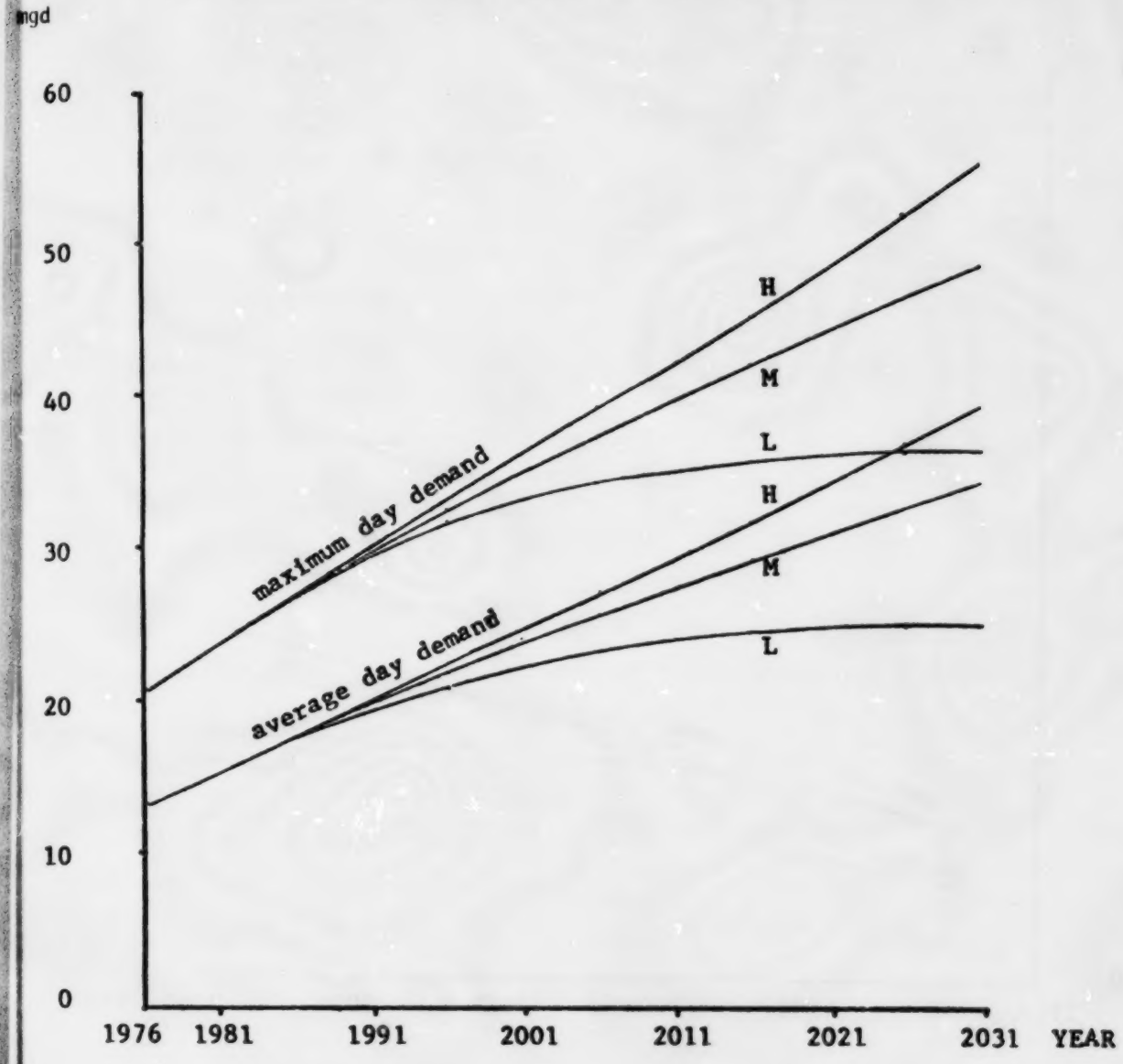
Base case projections are depicted in Figures 2.1 and 2.2. The figures indicate that population growth is a key determinant of water demand. Depending on which population projection is realized, combined capacity requirements set by maximum day use could vary up to 30 million gallons per day (mgd) (136 310 m^3/d) by the year 2031. If the medium population projection were met by the year 2031, capacity requirements would approach 70 mgd (318 190 m^3/d).

For each population projection, per capita consumption rates are projected to increase by about 5% of the observed 1978 consumption rates. This occurs because it was assumed that while residential consumption per household would remain constant, family size would decrease. The proportionately greater number of households raises the estimated future per capita pumpage rates. Alternatively, if household consumption rates were allowed to vary as a function of family size, the 5% increase projected by the projection would not likely be observed.

Base case and water conservation projections are summarized and compared in Tables 2.13 to 2.18. It is evident that the housing mix is not a critical parameter in forecasting demand. Substantially different assumptions about housing mix lead to a percentage difference of only 2% in demand and in the loading factor (Appendix C). The assumption about declining lot size is a more significant factor than housing mix since smaller lot sizes after 2001 cause the loading factor to fall by 5% to 9% between 1981 and 2031.

Under assumptions made for the low response water conservation projection, average day demand is 10% to 11% lower and maximum demand is 11% to 12% lower than those estimated in the base case projections. These savings are similar to savings which have been realized in actual case studies. However, they may be overly optimistic since certain water conservation measures have already been implemented. For the high response projection, average day demand and maximum day demand both fall by 19% to 21%.

Figure 2.1 Base Case Projections with Changing Housing Mix Using Low, Medium and High Population Projections for the City of Kitchener



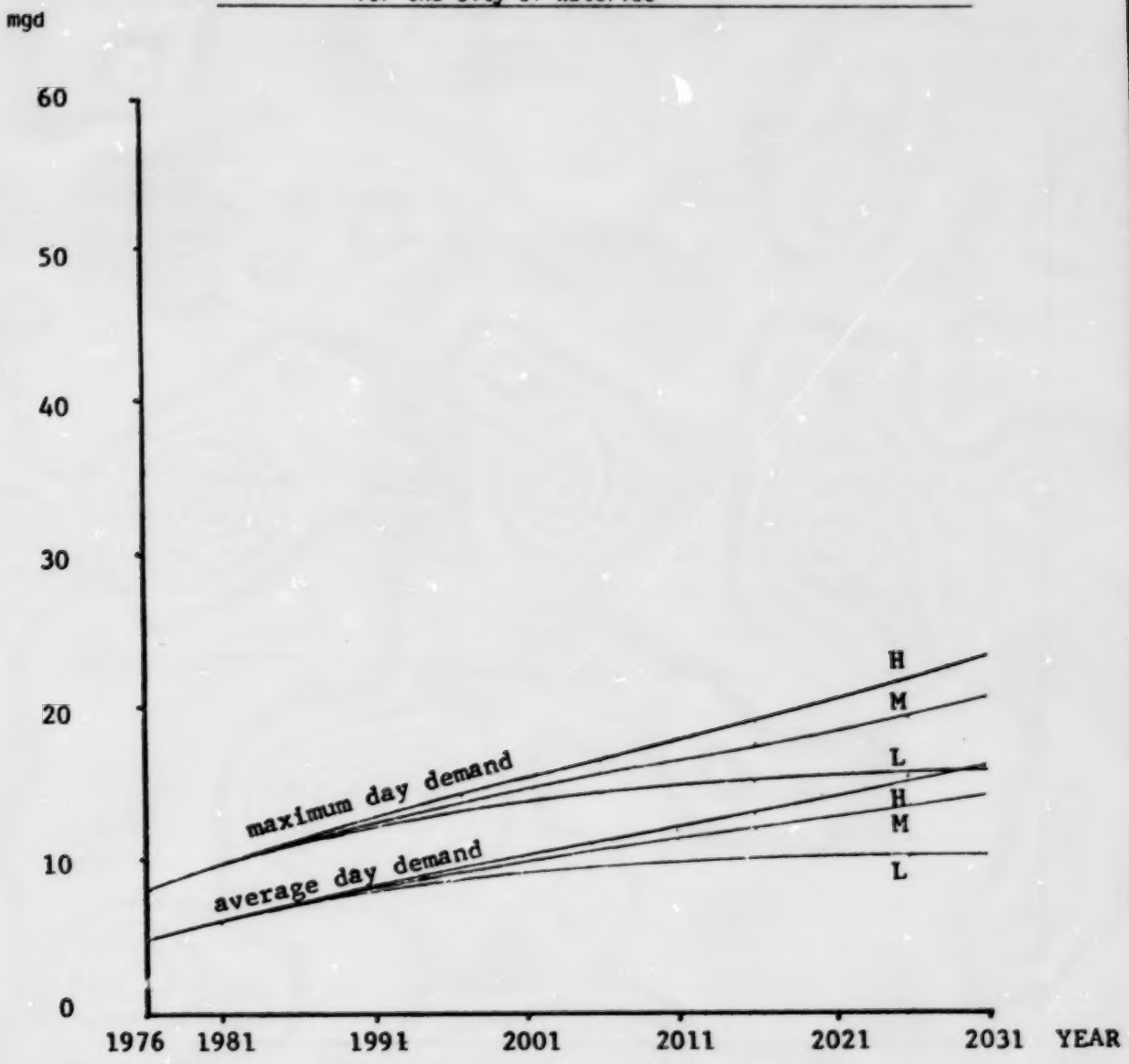
LEGEND

L - Low population projection

M - Medium population projection

H - High population projection

Figure 2.2 Base Case Projections with Changing Housing Mix Using Low, Medium and High Population Projections for the City of Waterloo



LEGEND

L - Low population projection

M - Medium population projection

H - High population projection

TABLE 2.13

Future Water Demands for the Low Population Projection - City of Kitchener

Year	Total Pumpage (mgd) Average Day	Maximum Day	Loading Factor	Average Day Per Capita Pumpage (gpcd)
Base Case - Fixed Housing Mix				
1981	15.27	23.70	1.55	103.6
2001	22.59	33.85	1.50	108.2
2031	24.83	36.89	1.49	108.1
Base Case - Changing Housing Mix				
1981	15.26	23.59	1.55	103.6
2001	22.55	33.22	1.47	108.0
2031	24.78	36.21	1.46	107.9
Water Conservation Case - Low Response				
1981	14.36	21.45	1.49	97.5
2001	20.43	29.41	1.44	97.8
2031	22.27	31.87	1.43	97.0
Water Conservation Case - High Response				
1981	13.12	19.87	1.51	89.1
2001	18.14	26.70	1.47	86.9

TABLE 2.14

Future Water Demands for the Low Population Projection - City of Waterloo

Year	Total Pumpage (mgd) Average Day	Maximum Day	Loading Factor	Average Day Per Capita Pumpage (gpcd)
Base Case - Fixed Housing Mix				
1981	5.94	9.54	1.61	100.8
2001	9.12	14.09	1.55	105.5
2031	10.02	15.35	1.53	105.4
Base Case - Changing Housing Mix				
1981	5.94	9.49	1.60	100.8
2001	9.11	13.81	1.52	105.3
2031	10.01	15.05	1.50	105.2
Water Conservation Case - Low Response				
1981	5.54	8.55	1.54	94.0
2001	8.18	12.10	1.48	94.6
2031	8.93	13.12	1.47	93.9
Water Conservation Case - High Response				
1981	4.94	7.84	1.58	84.4
2001	7.13	10.87	1.52	82.5
2031	7.75	11.75	1.51	81.5

TABLE 2.15

Future Water Demands for the Medium Population Projection - City of Kitchener

Year	Total Pumpage (mgd) Average Day	Maximum Day	Loading Factor	Average Day Per Capita Pumpage (gpcd)
Base Case - Fixed Housing Mix				
1981	15.27	23.71	1.55	103.6
2001	24.06	35.90	1.49	108.1
2031	34.40	49.79	1.45	107.7
Base Case - Changing Housing Mix				
1981	15.27	23.60	1.55	103.6
2001	24.01	35.23	1.47	107.9
2031	34.34	48.88	1.42	107.5
Water Conservation Case - Low Response				
1981	14.37	21.46	1.49	97.5
2001	21.64	31.07	1.44	97.3
2031	30.16	42.34	1.40	94.4
Water Conservation Case - High Response				
1981	13.13	19.88	1.51	89.1
2001	19.17	28.15	1.47	86.2

TABLE 2.16

Future Water Demands for the Medium Population Projection - City of Waterloo

Year	Total Pumpage (mgd) Average Day	Maximum Day	Loading Factor	Average Day Per Capita Pumpage (gpcd)
Base Case - Fixed Housing Mix				
1981	5.94	9.55	1.61	100.8
2001	9.71	14.94	1.54	105.4
2031	13.88	20.67	1.49	105.0
Base Case - Changing Housing Mix				
1981	5.94	9.50	1.60	100.8
2001	9.70	14.65	1.51	105.3
2031	13.86	20.28	1.46	104.8
Water Conservation Case - Low Response				
1981	5.54	8.55	1.54	94.0
2001	8.67	12.79	1.47	94.1
2031	12.13	17.43	1.44	91.7
Water Conservation Case - High Response				
1981	4.98	7.85	1.58	84.4
2001	7.54	11.46	1.52	81.8
2031	10.42	15.47	1.48	78.8

TABLE 2.17

Future Water Demands for the High Population Projection - City of Kitchener

Year	Total Pumpage (mgd) Average Day	Maximum Day	Loading Factor	Average Day Per Capita Pumpage (gpcd)
Base Case - Fixed Housing Mix				
1981	15.27	23.71	1.55	103.6
2001	25.02	37.23	1.49	108.1
2031	39.52	56.58	1.43	107.6
Base Case - Changing Housing Mix				
1981	15.27	23.60	1.55	103.6
2001	24.98	36.54	1.46	107.9
2031	39.45	55.55	1.41	107.4
Water Conservation Case - Low Response				
1981	14.37	21.46	1.49	97.5
2001	22.43	32.15	1.43	96.9
2031	34.37	47.85	1.39	93.6
Water Conservation Case - High Response				
1981	13.13	19.88	1.51	89.1
2001	19.84	29.10	1.47	85.7

TABLE 2.18

Future Water Demands for the High Population Projection - City of Waterloo

Year	Total Pumpage (mgd) Average Day	Maximum Day	Loading Factor	Average Day Per Capita Pumpage (gpcd)
Base Case - Fixed Housing Mix				
1981	5.94	9.55	1.61	100.8
2001	10.10	15.49	1.53	105.4
2031	15.94	23.47	1.47	104.8
Base Case - Changing Housing Mix				
1981	5.94	9.50	1.60	100.8
2001	10.09	15.19	1.51	105.2
2031	15.92	23.03	1.45	104.7
Water Conservation Case - Low Response				
1981	5.54	8.55	1.54	94.0
2001	9.00	13.24	1.47	93.8
2031	13.84	19.70	1.42	91.0
Water Conservation Case - High Response				
1981	4.98	7.85	1.58	84.4
2001	7.81	11.85	1.52	81.5
2031	11.84	17.43	1.47	77.9

The impact of various rate structures on water consumption is summarized in Tables 2.19 and 2.20.

Only three new rate structures were tested for Waterloo since the existing system already uses flat rate pricing. Neither the flat rate structure in Kitchener nor the increasing block rate structures in Kitchener and in Waterloo had significant impacts on consumption. The loading factor increased marginally with the increasing block rate because a lower price is levied on domestic lawn sprinkling. The two rate structures with special summer charges had a marked impact on maximum day demand and the loading factor. A seasonal surcharge depressed maximum day use by 7% to 9% while the more severe excess use rate depressed it by 13% to 19%. Impacts of this magnitude have been observed in practice (Table 2.8) and are quite close to the forecast low response water conservation case impacts.

To analyze the impact of increasing supply costs on water demand, a flat rate schedule was projected into the future. Several supply projects were considered in this analysis including induced infiltration, ground-water recharge at Mannheim, ground water from Roseville, and pipelines from the proposed Montrose and Ayr reservoirs and Lake Erie.

As evidenced in Figures 2.3 and 2.4 the expensive pipeline projects could have a considerable impact on consumption rates. In the limit defined by the upper range of price associated with the Lake Erie pipeline, average day demand falls by 11% and 13% and maximum day demand by 22% and 20% in Waterloo and Kitchener respectively.

The greater sensitivity of maximum day demand causes a progressive decline of the loading factor as price increases. However, these results should be received with the same reservations attached to any extrapolations using statistically calibrated models.

Four different projections based on medium population projections for the two cities are compared in Figures 2.5 and 2.6 including: (1) base case projection with a changing house mix, (2) water conservation projection,

TABLE 2.19

Impact of New Rate Structures on Water Consumption - City of Kitchener, 1978

Rate Structure	Existing Increasing Block	Flat Rate	Increasing Block	Seasonal Surcharge	Excess Use
Prices Charged[1] ($/1,000 gal):					
First block (3,115-105,910 gal/mo)	1.24	1.29	1.21	1.05	1.19
Second block (105,911-186,900 gal/mo)	1.12	1.29	1.32	1.05	1.19
Third block (>186,900 gal/mo)	1.03	1.29	1.43	1.05	1.19
Summer Rate	N/A	N/A	N/A	1.85	2.42
Average Day Pumpage:					
Total (mgd)	13.80	13.46	13.38	13.51	13.40
Per capita (gpcd)	103	101	100	101	100
Maximum Day Pumpage (mgd):	21.39	20.89	21.13	19.37	18.32
Loading Factor	1.55	1.55	1.58	1.43	1.37

[1]Prices include a sewer surcharge. $1.49/1,000 gal charged on water below 3,116 gallons per month under existing rates. Few consumers remain within this block.
N/A - Not applicable.

TABLE 2.20

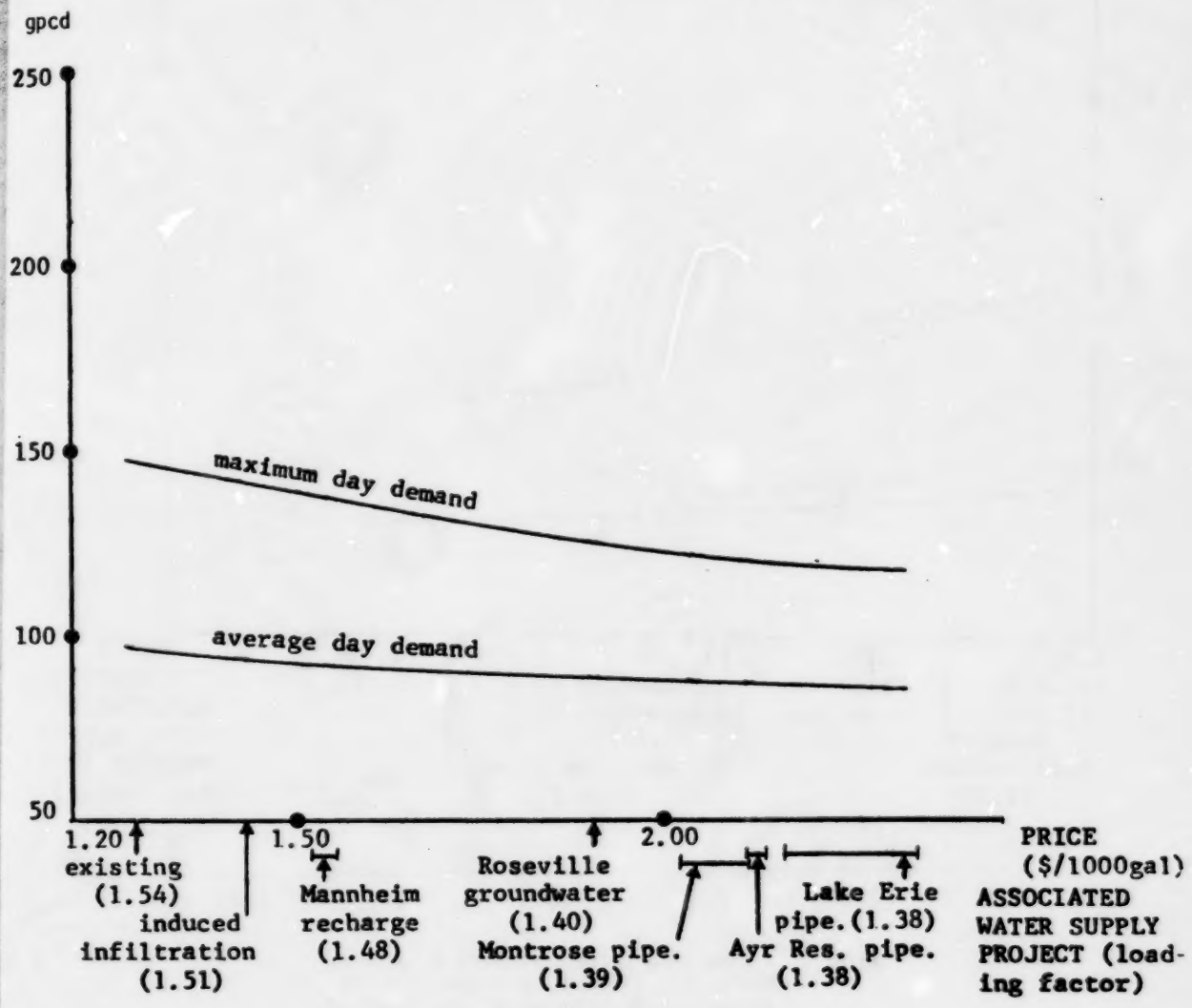
Impact of New Rate Structures on Water Consumption - City of Waterloo, 1978

Rate Structure	Existing Flat Rate	Increasing Block	Seasonal Surcharge	Excess Use
Prices Charged[1] ($/1,000 gal):				
First Block (3,115-105,911 gal/mo)	1.06	1.02	.88	1.02
Second Block (>105,911 gal/mo)	1.06	1.19	.88	1.02
Summer Rate	N/A	N/A	1.47	1.88
Average Day Pumpage:				
Total (mgd)	5.11	5.05	5.14	5.10
Per capita (gpcd)	99	98	100	99
Maximum Day Pumpage (mgd):	8.43	8.48	7.84	7.36
Loading Factor	1.65	1.68	1.53	1.44

[1]Prices include a sewer surcharge. Few customers would remain in the first block of 0-3,115 gallons per month in the increasing block rate test. Consumption blocks here were fashioned after those in Kitchener.

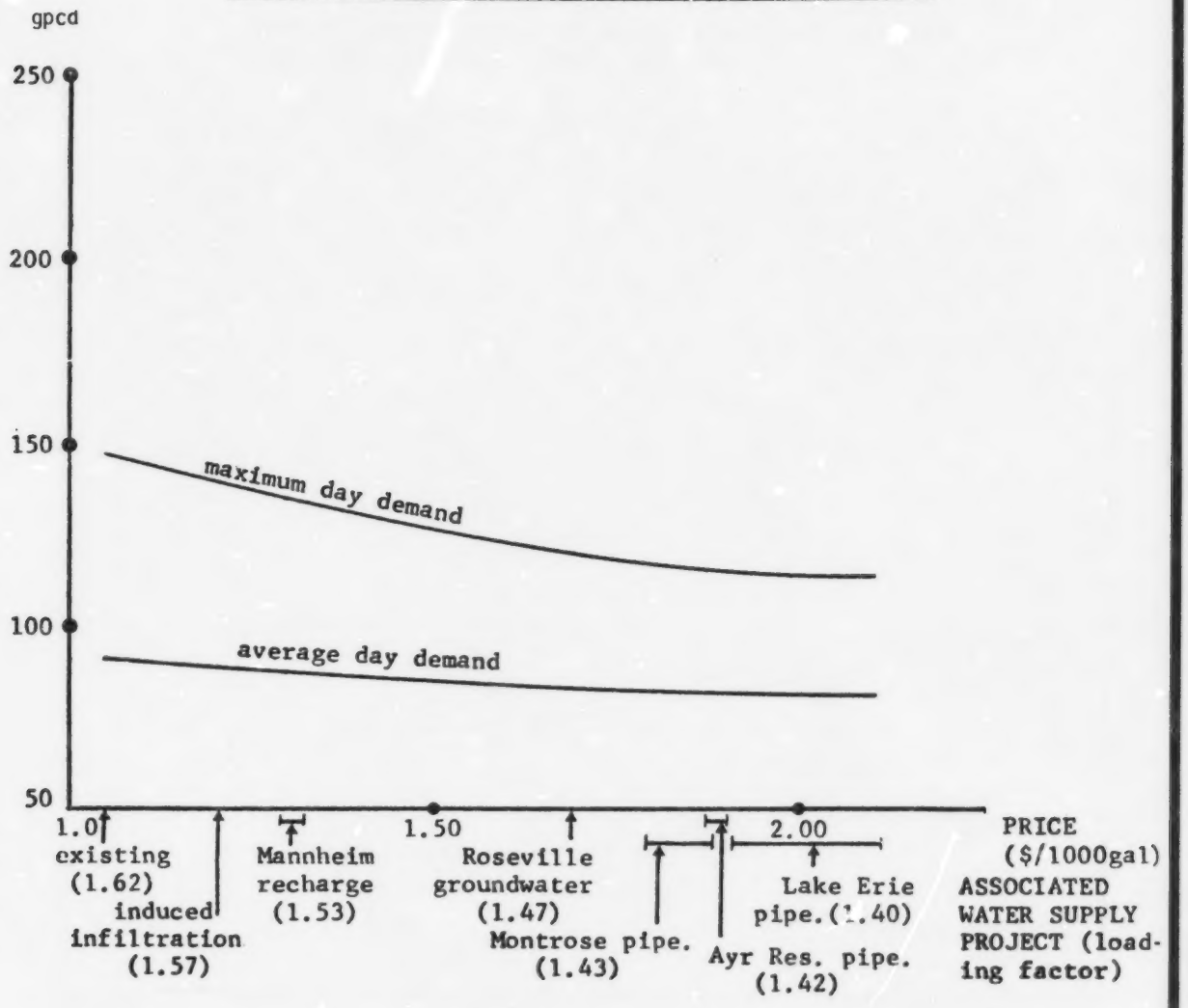
N/A - Not applicable.

Figure 2.3 Impact of Price on Per Capita Consumption Rates in the City of Kitchener, as Supply Costs Increase



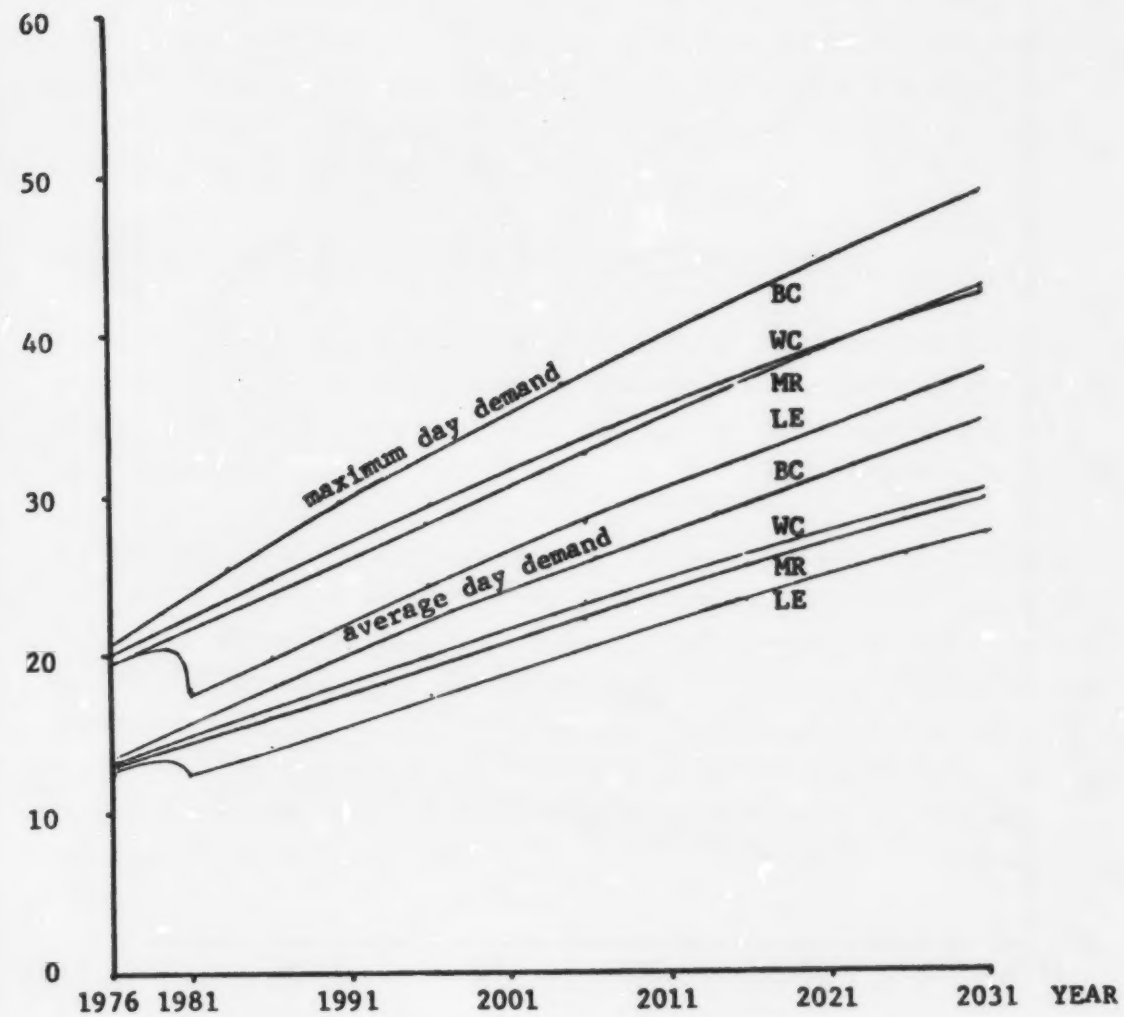
NOTE: - A flat rate price structure is assumed. Per capita consumption rates were not dignificantly affected by the level of population growth unless project costs varied with predicted growth rates.

Figure 2.4 Impact of Price on Per Capita Consumption Rates in the City of Waterloo as Supply Costs Increase



NOTE: - A flat rate price structure is assumed. Per capita consumption rates were not significantly affected by the level of population growth unless project costs varied with predicted growth rates.

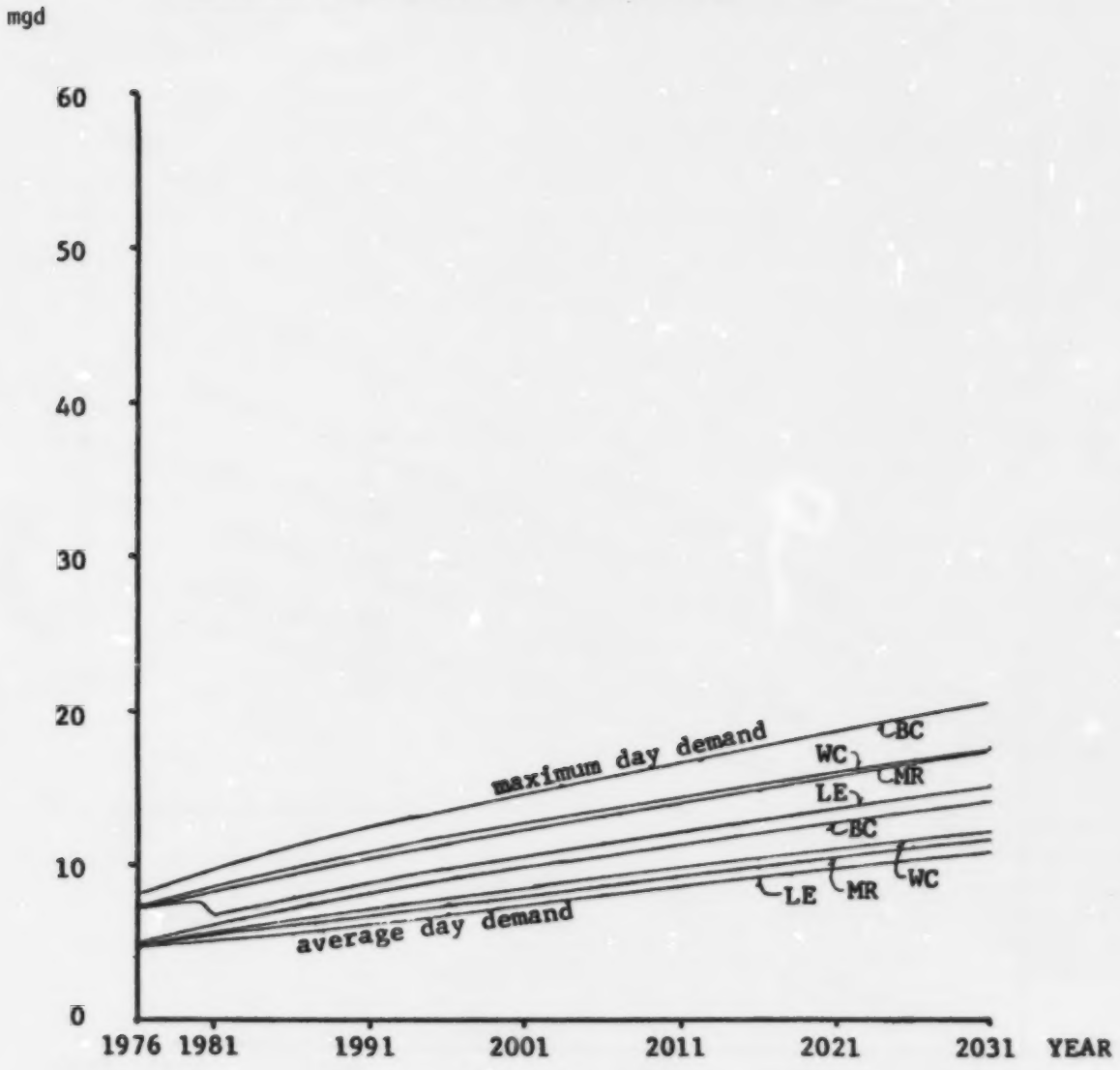
Figure 2.5 Comparison of Water Demand Projections Using Medium Population Projections for the City of Kitchener



LEGEND

BC - Base case with changing housing mix
WC - Water conservation, low response
MR - Pricing based on Mannheim recharge
LE - Pricing based on Lake Erie pipeline

Figure 2.6 Comparison of Water Demand Projections Using Medium Population Projections for the City of Waterloo



LEGEND

BC - Base case with changing housing mix
WC - Water conservation, low response
MR - Pricing based on Mannheim recharge
LE - Pricing based on Lake Erie pipeline

low response, (3) pricing based on Mannheim recharge, and (4) pricing base on Lake Erie pipeline. The lowest projections incorporated flat rate prices that reflect use of the Lake Erie pipeline. These show a precipitous drop in 1981, the year in which the project is assumed to be brought on line. The base case projection is invariably the highest projection since it fails to account for possible modifications in water consumption habits on the part of users. The weight of the evidence suggests that consumption will fall below the base projection implying a constant or falling per capita rate. However, the analysis here exaggerates these reductions because it fails to take into account the effects of past conservation efforts.

2.2.1.2 Water Demand Projections for the City of Cambridge

Generally, the discussion of projections made for Kitchener and Waterloo apply equally well for Cambridge. Population is a key factor in estimating demand, while the housing mix is not. A falling family size causes per capita consumption to increase (Tables 2.21 to 2.23 and Figure 2.7).

The water conservation programs used in this analysis are more effective than in Kitchener and Waterloo. This situation can be attributed to higher initial system losses and a large number of water intensive industries. For the low response case, average day demand falls 15% to 17% and maximum day demand falls 16% to 18%; for the high response case corresponding changes are 24% to 27% and 24% to 26%. With the low response case, per capita consumption falls to levels observed elsewhere in the Regional Municipality of Waterloo.

Flat rate and increasing block rate pricing have little impact on overall demand. Essentially, they tend to reallocate demand so that domestic consumption increases while industrial consumption falls. All consumers face higher summer prices under the seasonal surcharge and excess use schemes so that maximum day consumption falls off by up to 14% (Table 2.24).

TABLE 2.21

Future Water Demands for the Low Population Projection - City of Cambridge

Year	Total Pumpage (mgd) Average Day	Maximum Day	Loading Factor	Average Day Per Capita Pumpage (gpcd)
Base Case - Fixed Housing Mix				
1981	9.67	14.60	1.51	116.0
2001	14.17	20.83	1.47	121.3
2031	15.57	22.75	1.46	121.2
Base Case - Changing Housing Mix				
1981	9.67	14.46	1.50	115.9
2001	14.13	20.03	1.42	120.9
2031	15.53	21.97	1.41	120.9
Water Conservation Case - Low Response				
1981	8.79	12.81	1.46	105.4
2001	11.77	16.63	1.41	100.8
2031	12.70	17.92	1.41	98.8
Water Conservation Case - High Response				
1981	7.98	11.82	1.48	95.7
2001	10.38	15.01	1.45	88.8

TABLE 2.22

Future Water Demands for the Medium Population Projection - City of Cambridge

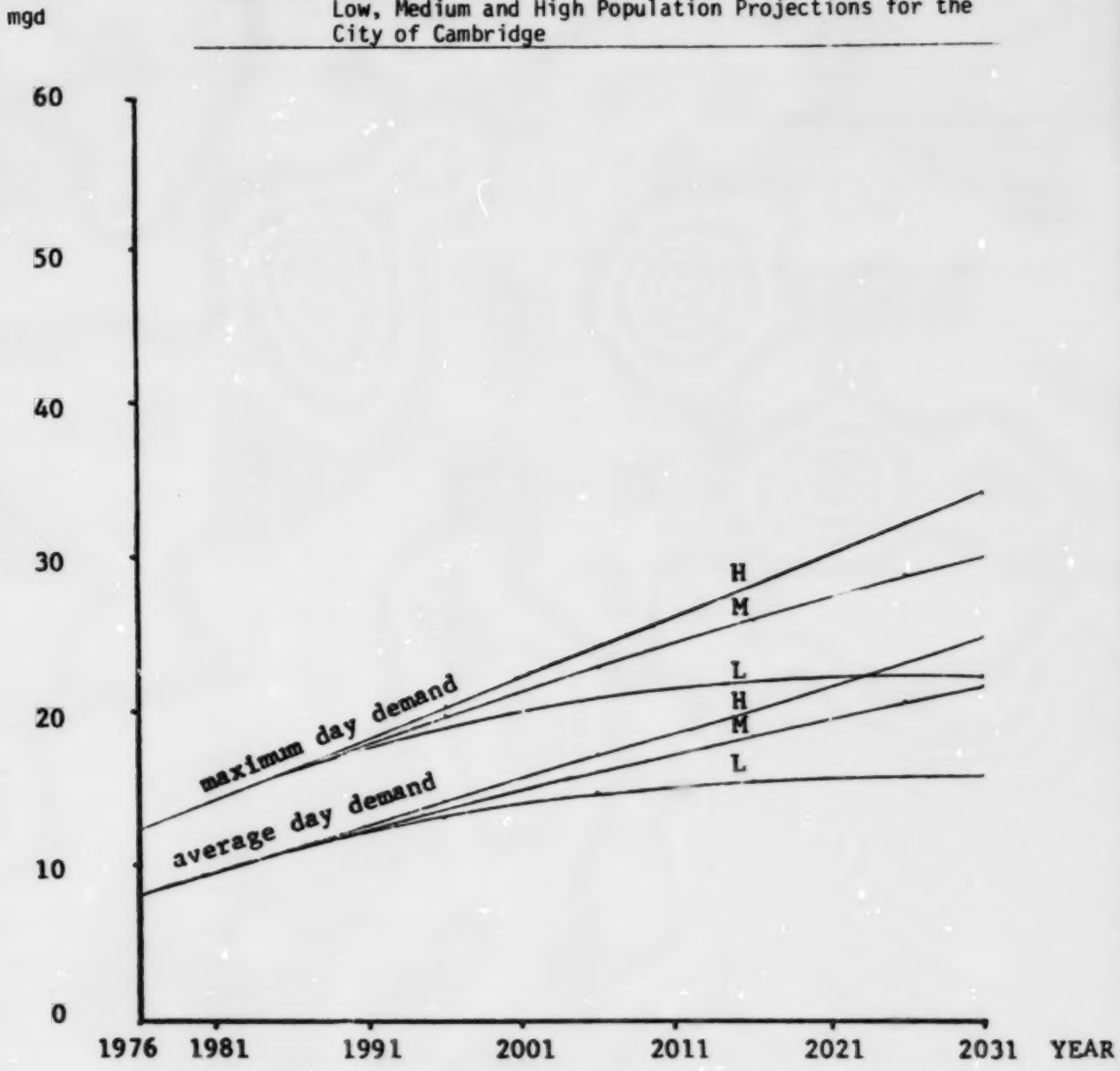
Year	Total Pumpage (mgd) Average Day	Maximum Day	Loading Factor	Average Day Per Capita Pumpage (gpcd)
Base Case - Fixed Housing Mix				
1981	9.68	14.61	1.51	116.0
2001	15.09	22.12	1.47	121.2
2031	21.60	30.94	1.43	120.9
Base Case - Changing Housing Mix				
1981	9.67	14.47	1.50	115.9
2001	15.05	21.30	1.42	120.9
2031	21.55	29.92	1.39	120.6
Water Conservation Case - Low Response				
1981	8.80	12.82	1.46	105.4
2001	12.38	17.50	1.41	99.5
2031	16.63	23.30	1.40	93.1
Water Conservation Case - High Response				
1981	7.99	11.82	1.48	95.7
2001	10.87	15.76	1.45	87.4
2031	14.37	20.72	1.44	80.4

TABLE 2.23

Future Water Demands for the High Population Projection - City of Cambridge

Year	Total Pumpage (mgd) Average Day	Maximum Day	Loading Factor	Average Day Per Capita Pumpage (gpcd)
Base Case - Fixed Housing Mix				
1981	9.68	14.61	1.51	116.0
2001	15.70	22.96	1.46	121.2
2031	24.83	35.28	1.42	120.8
Base Case - Changing Housing Mix				
1981	9.67	14.47	1.50	115.9
2001	15.66	22.14	1.41	120.9
2031	24.77	34.14	1.38	120.5
Water Conservation Case - Low Response				
1981	8.80	12.82	1.46	105.4
2001	12.78	18.05	1.41	98.6
2031	18.73	26.14	1.40	91.2
Water Conservation Case - High Response				
1981	7.99	11.82	1.48	95.7
2001	11.20	16.23	1.45	86.5
2031	16.10	23.16	1.44	78.3

Figure 2.7 Base Case Projections with Changing Housing Mix Using Low, Medium and High Population Projections for the City of Cambridge



LEGEND

L - Low population projections

M - Medium population projections

H - High population projections

TABLE 2.24

Impact of New Rate Structures on Water Consumption - City of Cambridge, 1978

Rate Structure	Existing Increasing Block	Flat Rate	Increasing Block	Seasonal Surcharge	Excess Use
Prices Charged[1] ($/1,000 gal):					
First Block (0-75,000 gal/mo)	1.07	1.01	.99	.82	.99
Second Block (>75,000 gal/mo)	.87	1.01	1.21	.82	.99
Summer Rate	N/A	N/A	N/A	1.52	2.08
Average Day Pumpage:					
Total (mgd)	8.37	8.30	8.18	8.34	8.27
Per capita (gpcd)	115	114	112	114	113
Maximum Day Pumpage (mgd):	12.89	12.98	12.93	11.92	11.10
Loading Factor	1.54	1.56	1.58	1.43	1.34

[1]Prices include sewer surcharge.
N/A - Not applicable.

The impact of future costs on consumption may be important in Cambridge because of the likelihood of high supply costs in the future. The anticipated range of costs for Cambridge is similar to the range for Kitchener and Waterloo. The Lake Erie pipeline is cheaper on a unit basis for Cambridge because of the need for an additional pumping station to lift the water from Cambridge to Kitchener. If the Cambridge system is connected to Kitchener, then supply costs for projects like the Mannheim recharge scheme and the reservoir pipelines will determine water prices in Cambridge. Over the anticipated price range, average day demand falls 12% and maximum day demand falls 22%. The loading factor falls by 12% (Figure 2.8).

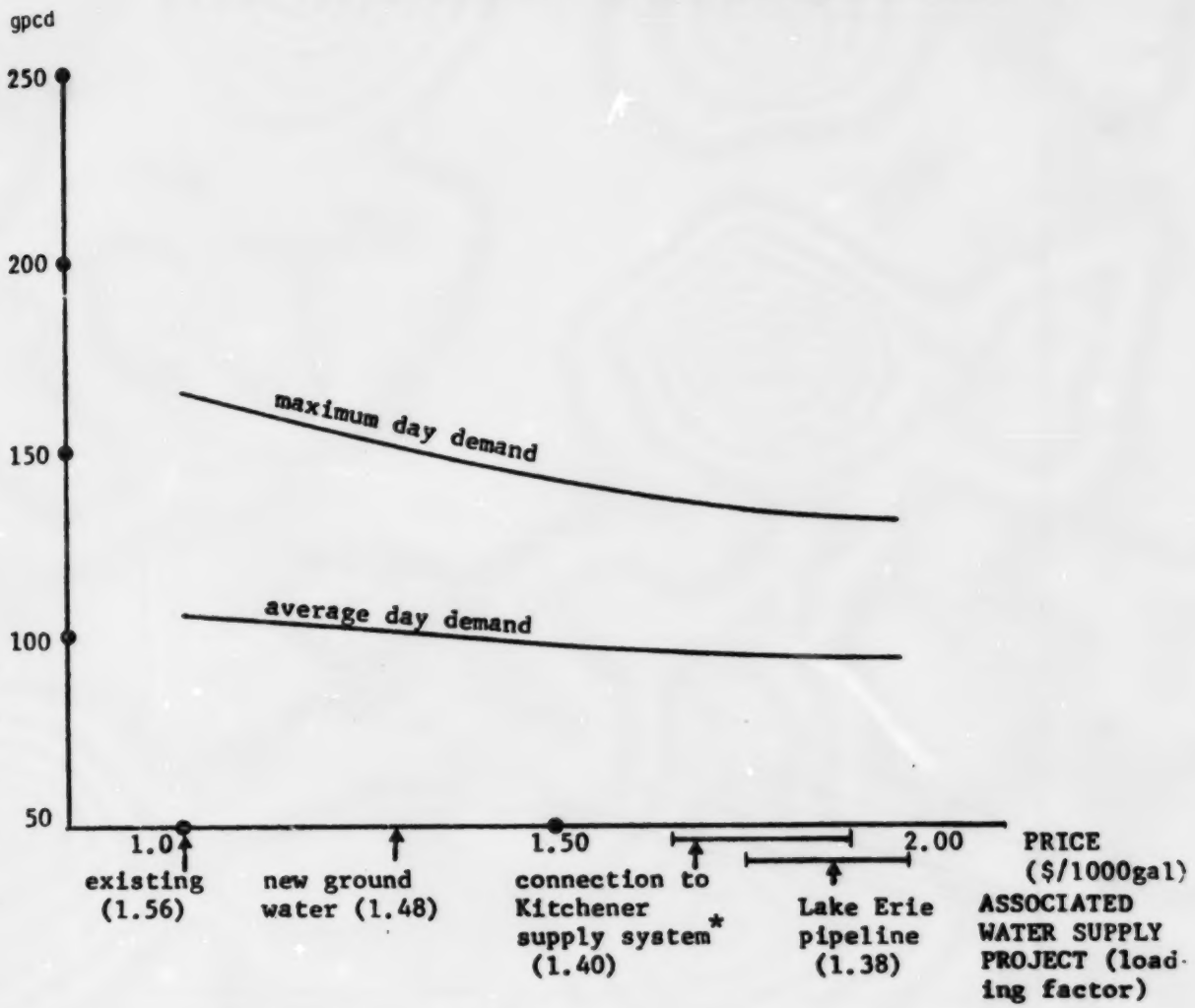
Four different projections based on the medium population projection for the City are compared in Figure 2.9 including: (1) base case projection with a changing housing mix, (2) water conservation projection, low response, (3) pricing based on Mannheim recharge, and (4) pricing based on Lake Erie pipeline. The Lake Erie pipeline pricing projection lies closer to the Mannheim recharge projection than in the Kitchener and Waterloo projections because the associated prices are closer. The base case projection is consistently above the other projections which are all relatively close to each other. Actual demand will probably fall below the base case as inexpensive supplies are exhausted.

2.2.1.3 Water Demand Projections for the City of Guelph

The base case projection for the City of Guelph is outlined in Figure 2.10. As with the Cities of Kitchener and Waterloo, population growth is a key determinant of water demand. By the year 2031, capacity requirements based on maximum day use could vary by 30 mgd (136.37 m^3/d) depending on which population projection is realized. Per capita increases were noted in the base case projections since family size was assumed to decrease while household consumption was assumed to remain constant.

The low response water conservation projection reduces average day demand by 13% to 21% and maximum day demand by 15% to 21%. For the high response case, average day demand decreases by 22% to 30% and maximum day demand

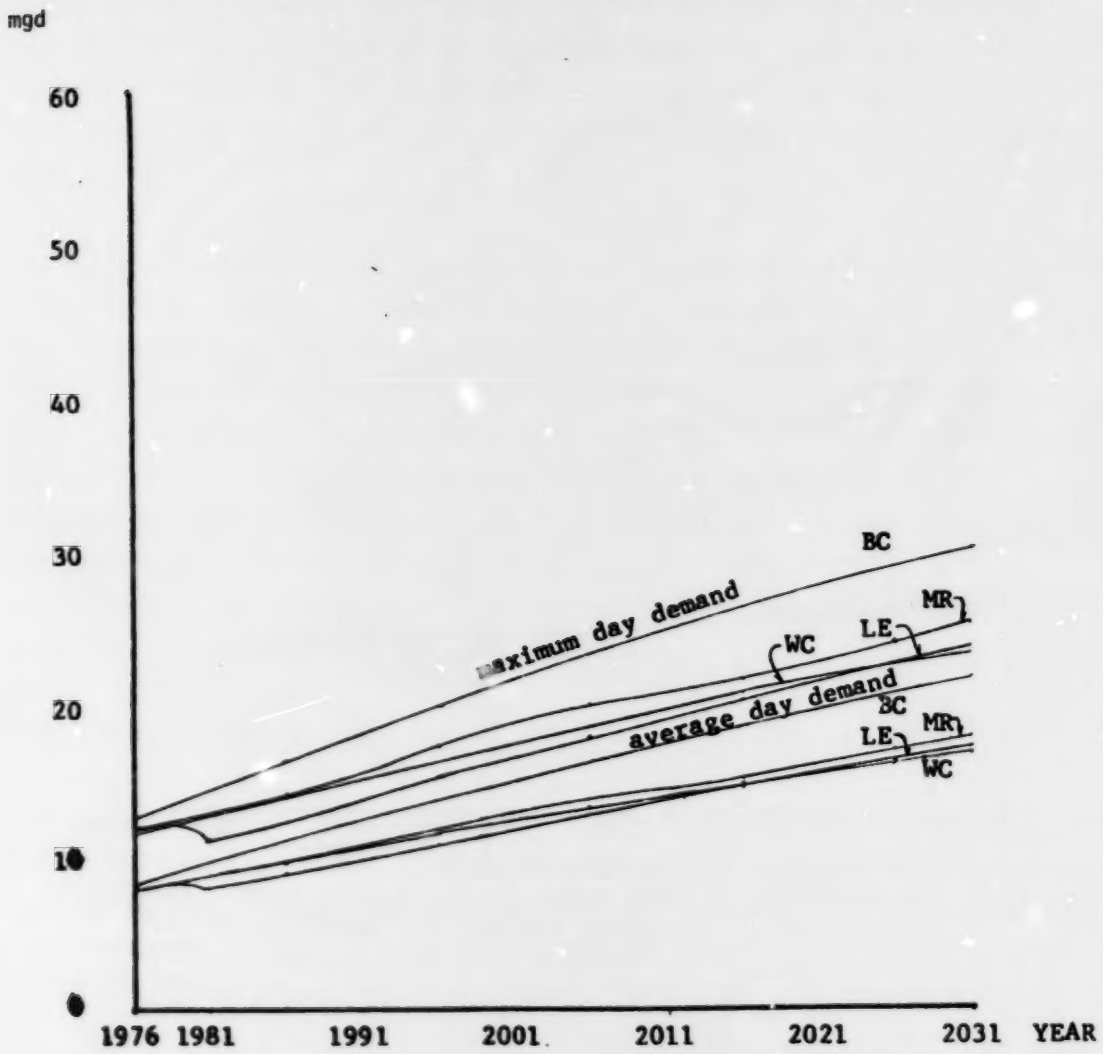
Figure 2.8 Impact of Price on Per Capita Consumption Rates in the City of Cambridge as Supply Costs Increase



NOTE: - A flat rate price structure is assumed. Per capita consumption rates were not significantly affected by the level of population growth unless project costs varied with predicted growth rates.

* With a connection to the Kitchener/Waterloo system, the price depends on the type of supply system in Kitchener/Waterloo.

Figure 2.9 Comparison of Water Demand Projections Using Medium Population Projections for the City of Cambridge



LEGEND

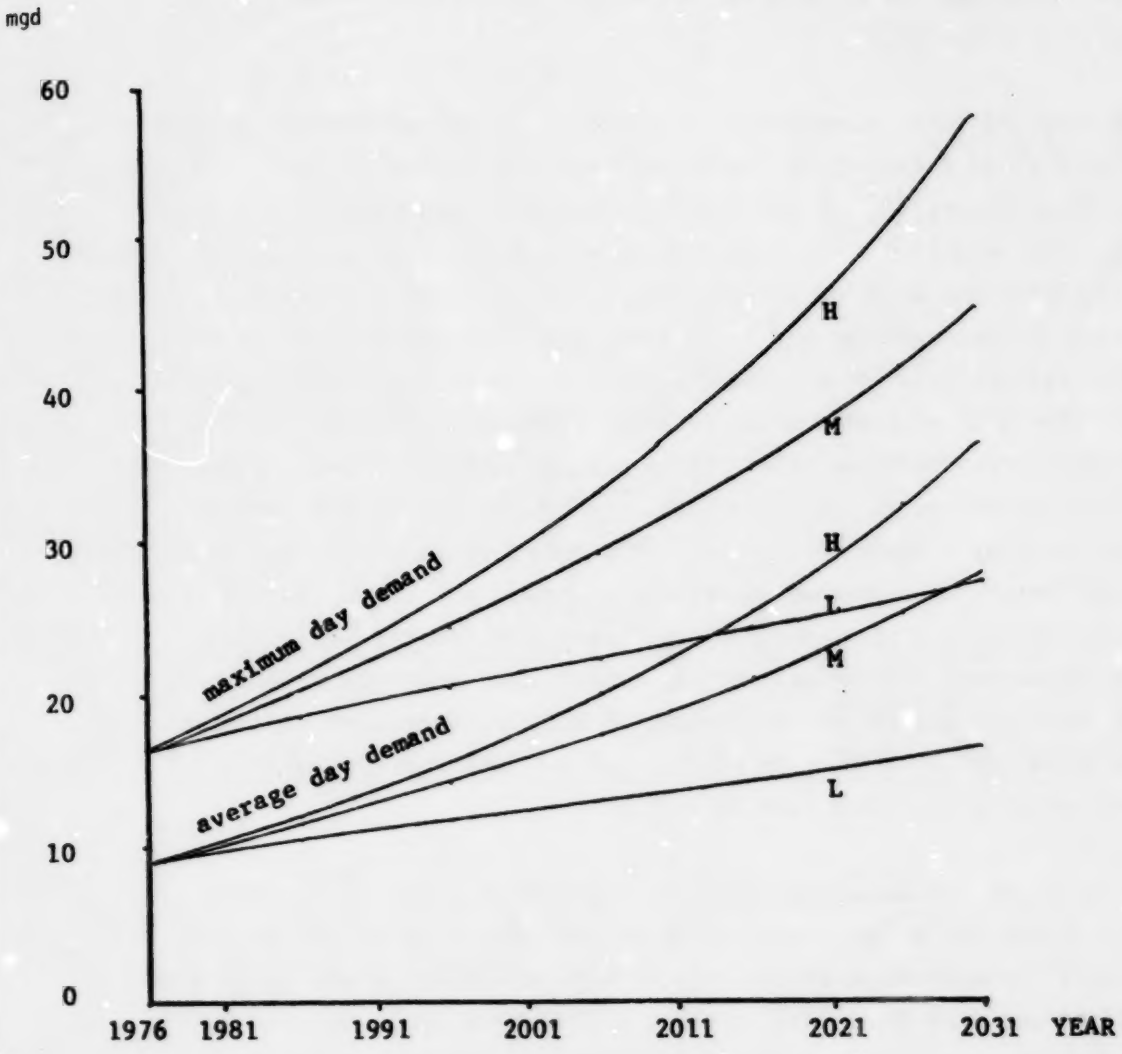
BC - Base case with changing housing mix

MR - Pricing based on Mannheim recharge

LE - Pricing based on Lake Erie pipeline

WC - Water conservation, low response

Figure 2.10 Base Case Projections with Changing Housing Mix Using Low, Medium and High Population Projections for the City of Guelph



LEGEND

L - Low population projection

M - Medium population projection

H - High population projection

falls by 22% to 28%. The impact of water conservation is greater in Guelph than in Kitchener and Waterloo because system losses are initially higher (23% compared to 10% and 12%) and because the existing industrial mix is more heavily weighted towards large scale consumers (Table 2.4). Therefore, the potential for savings is greater. Conversely, the need for conservation may not be as great because of the current robust supply situation in Guelph.

Base case and water conservation projections are summarized and compared in Tables 2.25 to 2.27. These tables indicate that the assumptions used regarding housing mix are not critical in forecasting water demand for the City. The impact of a new rate structure is more prominent in Guelph than in Kitchener and Waterloo because demand curves are more sensitive to price changes in the lower regions (low price, high consumption) than in the higher regions (high price, low consumption) and Guelph's starting point is lower than that of Kitchener or Waterloo. Consequently, both the flat rate and the increasing block rates reduce per capita consumption. However, maximum day demand is not significantly affected because home owners actually enjoy a lower unit price. This reduction in price comes about because water sales revenue is assumed to remain unchanged. With falling average day and constant maximum day demand, the loading factor rises. Both the average and the maximum day demands fall under the rate structures that include a special summer charge. Predicted changes are consistent with actual conservation case studies but are less than the water conservation projections (see Table 2.8)

The impact of rising supply costs are depicted in Figure 2.11. This analysis may not be applicable since distant ground-water sources are currently considered necessary only if high population growth rates are realized and even then, local sources will suffice up to the year 2026. The distant ground-water supplies have not been carefully identified or costed. As with values in Table 2.27, the slope of lines in Figure 2.12 indicate the potential for price induced reductions in consumption in Guelph.

TABLE 2.25

Future Water Demands for the Low Population Projection - City of Guelph

Year	Total Pumpage (mgd) Average Day	Maximum Day	Loading Factor	Average Day Per Capita Pumpage (gpcd)
Base Case - Fixed Housing Mix				
1981	9.80	17.54	1.79	129.0
2001	12.41	21.60	1.74	134.5
2031	16.58	28.08	1.69	134.1
Base Case - Changing Housing Mix				
1981	9.80	17.51	1.79	129.0
2001	12.40	21.37	1.72	134.4
2031	16.57	27.76	1.68	134.0
Water Conservation Case - Low Response				
1981	9.16	15.67	1.71	120.6
2001	10.77	18.13	1.68	116.7
2031	13.22	22.18	1.68	106.9
Water Conservation Case - High Response				
1981	8.39	14.59	1.74	110.5
2001	9.65	16.67	1.73	104.6

TABLE 2.26

Future Water Demands for the Medium Population Projection - City of Guelph

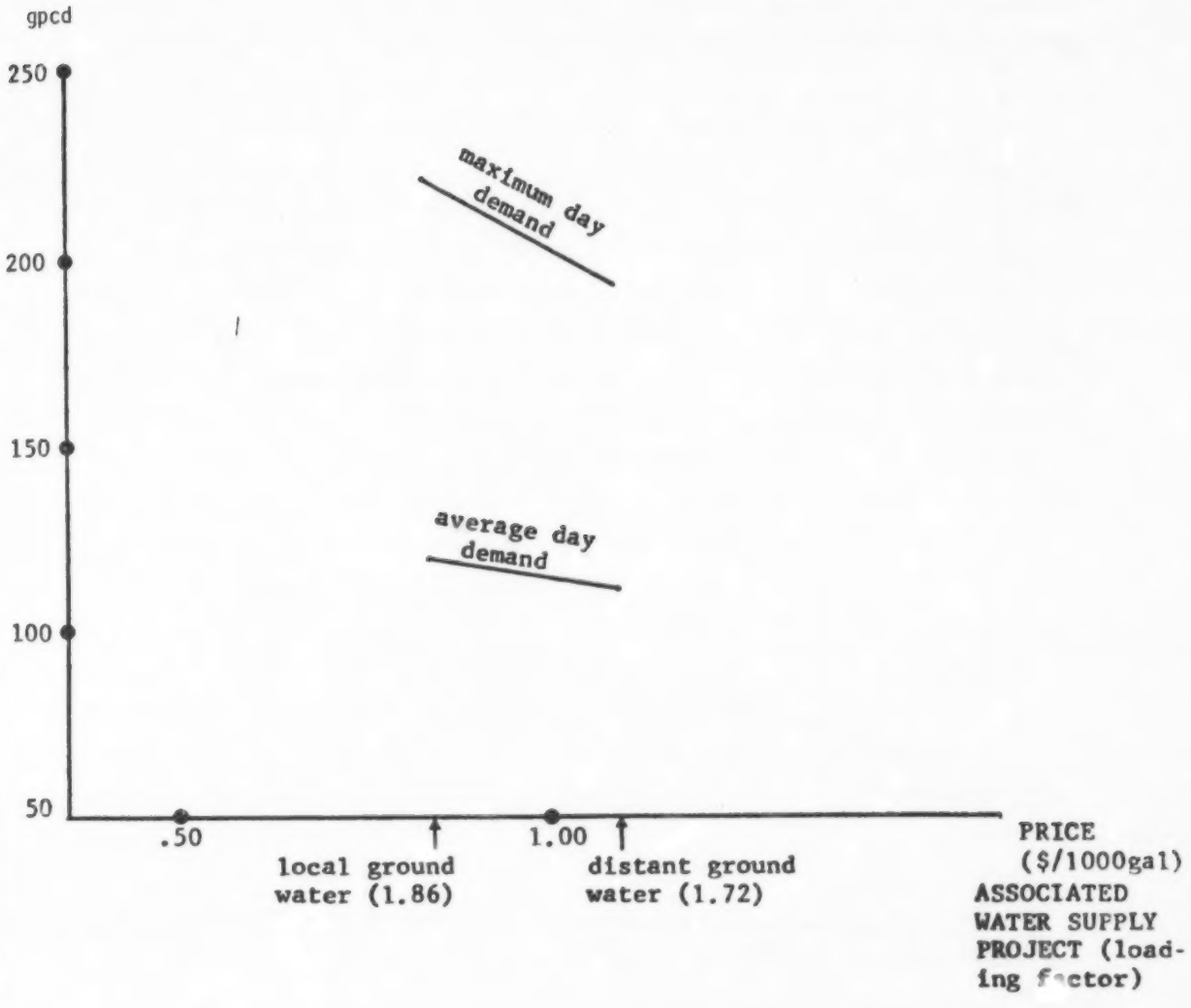
Year	Total Pumpage (mgd) Average Day	Maximum Day	Loading Factor	Average Day Per Capita Pumpage (gpcd)
Base Case - Fixed Housing Mix				
1981	10.28	18.38	1.79	129.0
2001	15.77	27.10	1.72	134.3
2031	28.19	46.11	1.64	133.5
Base Case - Changing Housing Mix				
1981	10.28	18.34	1.78	129.0
2001	15.76	26.77	1.70	134.2
2031	28.15	45.44	1.61	133.4
Water Conservation Case - Low Response				
1981	9.44	16.20	1.72	118.4
2001	12.75	21.58	1.69	108.5
2031	20.04	33.36	1.66	94.9
Water Conservation Case - High Response				
1981	8.62	15.07	1.75	108.2
2001	11.27	19.68	1.75	95.9
2031	17.22	29.91	1.74	81.5

TABLE 2.27

Future Water Demands for the High Population Projection - City of Guelph

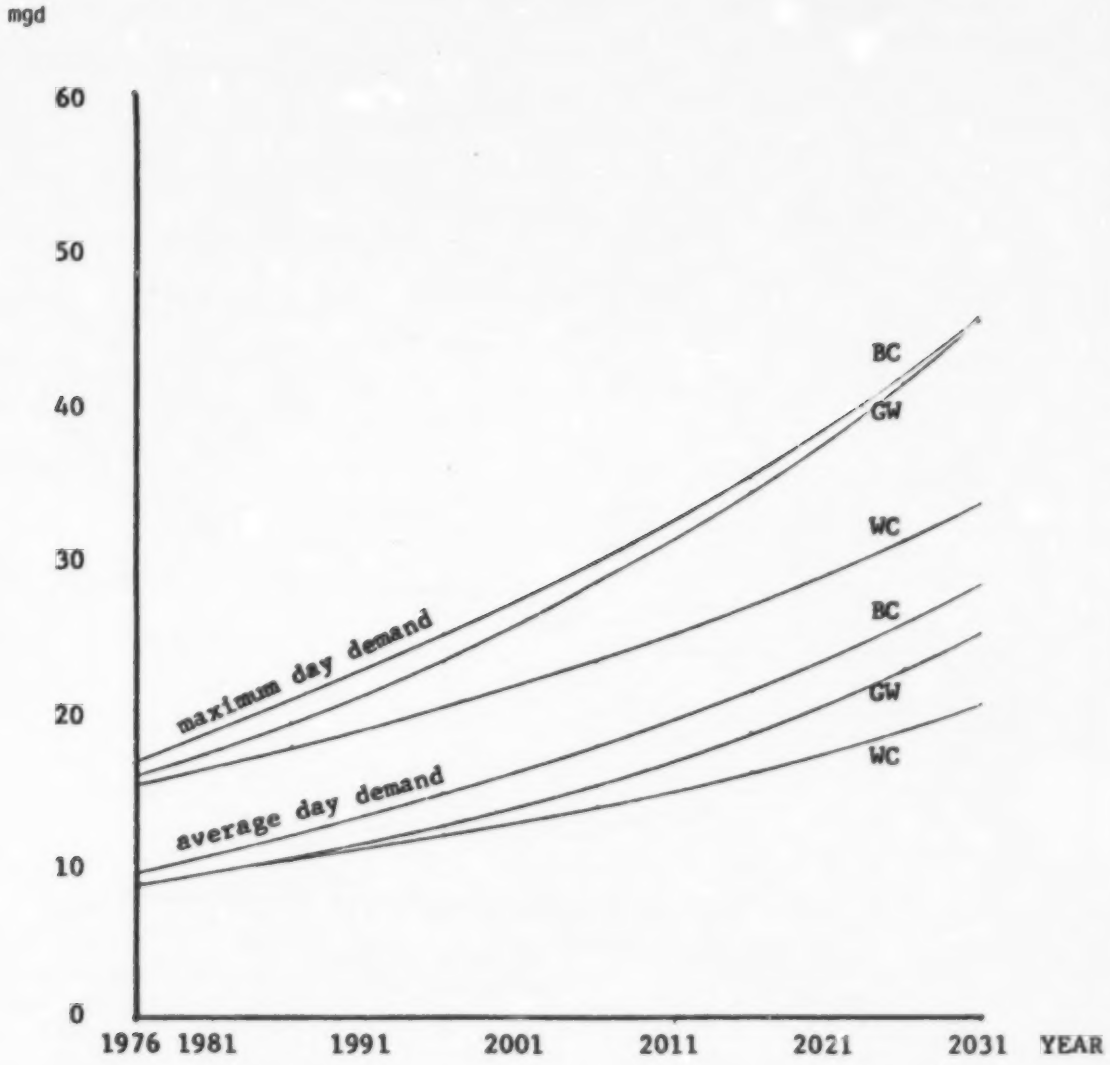
Year	Total Pumpage (mgd) Average Day	Maximum Day	Loading Factor	Average Day Per Capita Pumpage (gpcd)
Base Case - Fixed Housing Mix				
1981	10.53	18.81	1.79	129.0
2001	17.77	30.34	1.71	134.2
2031	36.72	59.08	1.61	133.2
Base Case - Changing Housing Mix				
1981	10.53	18.77	1.78	129.0
2001	17.76	29.95	1.69	134.0
2031	36.67	58.13	1.59	133.0
Water Conservation Case - Low Response				
1981	9.58	16.48	1.72	117.4
2001	13.92	23.60	1.69	105.1
2031	25.05	41.36	1.65	90.9
Water Conservation Case - High Response				
1981	8.74	15.31	1.75	107.1
2001	12.23	21.45	1.75	92.3
2031	21.30	36.85	1.73	77.3

Figure 2.11 Impact of Price on Per Capita Consumption Rates in the City of Guelph as Supply Costs Increase



NOTE: - A flat rate price structure is assumed. Per capita consumption rates were not significantly affected by the level of population growth unless project costs varied with predicted growth rates.

Figure 2.12 Comparison of Water Demand Projections Using Medium Population Projections for the City of Guelph



LEGEND

BC - Base case with changing housing mix
GW - Pricing based on new ground water
WC - Water conservation, low response

The various projections are compared in Figure 2.12. The base case projection depicts the highest consumption. The pricing projection incorporates only local ground water and some recharge from the Eramosa River so that unit prices do not change. This projection generates consumption rates lower than the base case projection because of the use of a flat rate price instead of the actual increasing block rate (Table 2.28). If circumstances do not change dramatically, then the base case projection is a reasonable estimate of water demand for the City of Guelph.

2.2.1.4 Water Demand Projections for the City of Brantford

In some key respects, Brantford's water supply system differs from systems in other basin cities. It is the only city relying on treated surface water extracted from the Grand River. Since the supply system is not limited by the need to go a great distance to secure an adequate volume of water, capacity is limited primarily by the size of the treatment plant. Brantford has the greatest concentration of water intensive industries in the basin while city residents enjoy the lowest water price in the basin because of the absence of a unit sewer surcharge on small meters. Consequently, per capita consumption rates in Brantford are among the highest observed within the basin.

As was indicated for the other cities, population is a principal determinant of water demand while housing mix is of little consequence. Per capita use increases as family size falls because of the proportionately greater number of households in the City (Tables 2.29 to 2.31 and Figure 2.13).

The water conservation projections have a considerable impact on consumption in Brantford. This is a result of the current high level of losses and the heavy industrial use. The low response case reduces average day demand by 14% to 21% and maximum day demand by 16% to 20%. The high response case impacts are respectively 21% to 28% and 21% to 26%.

The rate structure analysis generates some anomalous results because of the low rate on the first block covering residential use. For each of the new

TABLE 2.28

Impact of New Rate Structures on Water Consumption - City of Guelph, 1978

Rate Structure	Existing Increasing Block	Flat Rate	Increasing Block	Seasonal Surcharge	Excess Use
Prices Charged[1] ($/1,000 gal):					
First block (0-50,000 gal/mo)	.94	.84	.68	.61	.83
Second block (50,000-300,000 gal/mo)	.77	.84	.95	.61	.83
Third block (300,000-12x10^6 gal/mo)	.60	.84	1.22	.61	.83
Summer Rate	N/A	N/A	N/A	1.51	2.42
Average Day Pumpage:					
Total (mgd)	9.38	8.69	8.54	8.70	8.50
Per capita (gpcd)	131	122	120	122	119
Maximum Day Pumpage (mgd):	15.94	15.75	16.66	13.49	11.99
Loading Factor	1.70	1.81	1.95	1.55	1.41

[1]Prices include sewer surcharge. $.43/1,000 gal is charged on consumption above 12x10^6 gal per month under existing rates. Few customers are found in this block.
N/A - Not applicable.

TABLE 2.29

Future Water Demands for the Low Population Projection - City of Brantford

Year	Total Pumpage (mgd) Average Day	Maximum Day	Loading Factor	Average Day Per Capita Pumpage (gpcd)
Base Case - Fixed Housing Mix				
1981	9.45	16.86	1.78	134.4
2001	11.75	20.64	1.76	136.9
2031	15.79	27.05	1.71	136.5
Base Case - Changing Housing Mix				
1981	9.45	16.85	1.78	134.4
2001	11.73	20.36	1.74	136.7
2031	15.76	26.69	1.69	136.3
Water Conservation Case - Low Response				
1981	8.87	15.13	1.71	126.1
2001	10.06	17.21	1.71	117.2
2031	12.06	20.91	1.73	104.3
Water Conservation Case - High Response				
1981	8.31	14.27	1.72	118.1
2001	9.27	16.09	1.74	108.0

TABLE 2.30

Future Water Demands for the Medium Population Projection - City of Brantford

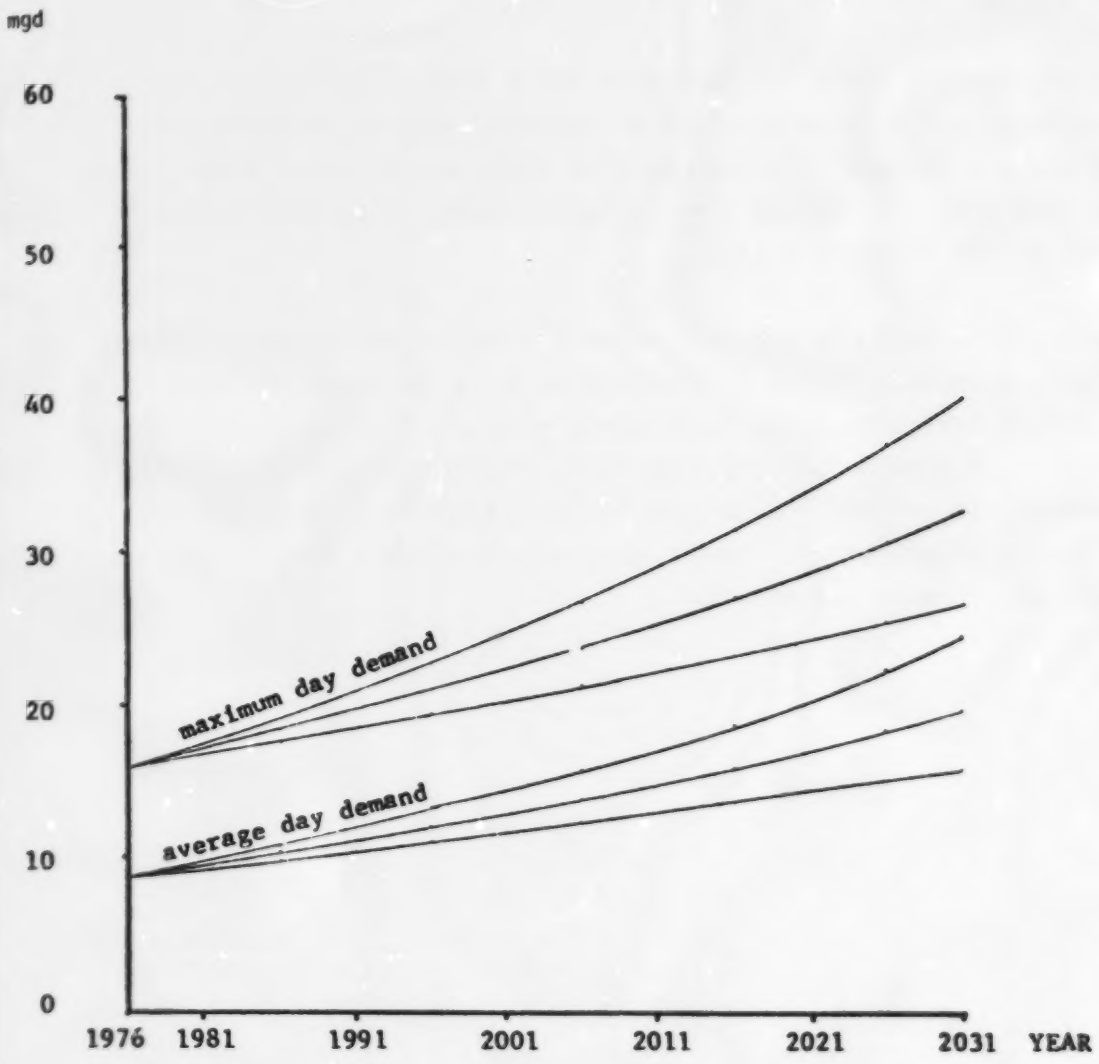
Year	Total Pumpage (mgd) Average Day	Maximum Day	Loading Factor	Average Day Per Capita Pumpage (gpcd)
Base Case - Fixed Housing Mix				
1981	9.65	17.20	1.78	134.4
2001	13.00	22.72	1.75	136.8
2031	19.71	33.31	1.69	136.3
Base Case - Changing Housing Mix				
1981	9.65	17.19	1.78	134.4
2001	12.98	22.43	1.73	136.6
2031	19.67	32.83	1.67	136.1
Water Conservation Case - Low Response				
1981	8.97	15.33	1.71	124.9
2001	10.68	18.43	1.73	112.4
2031	14.00	24.53	1.75	96.9
Water Conservation Case - High Response				
1981	8.39	14.46	1.72	116.9
2001	9.78	17.17	1.75	103.0
2031	12.54	22.57	1.80	86.8

TABLE 2.31

Future Water Demands for the High Population Projection - City of Brantford

Year	Total Pumpage (mgd) Average Day	Maximum Day	Loading Factor	Average Day Per Capita Pumpage (gpcd)
Base Case - Fixed Housing Mix				
1981	9.84	17.54	1.78	134.4
2001	14.37	24.99	1.74	136.8
2031	24.58	41.02	1.67	136.2
Base Case - Changing Housing Mix				
1981	9.84	17.53	1.78	134.4
2001	14.35	24.66	1.72	136.5
2031	24.53	40.39	1.65	135.9
Water Conservation Case - Low Response				
1981	9.06	15.54	1.71	123.7
2001	11.36	19.76	1.74	108.1
2031	16.42	28.96	1.76	91.0
Water Conservation Case - High Response				
1981	8.47	14.64	1.73	115.6
2001	10.35	18.36	1.77	98.5
2031	14.54	26.49	1.82	80.6

Figure 2.13 Base Case Projections with Changing Housing Mix Using Low, Medium and High Population Projections for the City of Brantford



LEGEND

L - Low population projections

M - Medium population projections

H - High population projections

rate structures that were tested, the price to households falls because water sales revenue are assumed to remain constant. For the flat rate and increasing block rate schedules, maximum day use increases 11% to 39%. The seasonal surcharge results in little overall change while the excess use rate drops maximum day use by 13%. Per capita consumption changes little with each new rate (Table 2.32).

Only two supply projects are considered for Brantford; maintenance and expansion of the existing river water treatment plant or replacement of this system with water from the Lake Erie pipeline. Price increases associated with the pipeline have a dramatic impact on maximum day demand as can be seen in Figure 2.14.

Results of the base case and river water pricing projections are virtually the same as shown in Figure 2.15 because no price increases are foreseen in the pricing projection. The low response water conservation projection and the Lake Erie pipeline pricing projections are both below the base case projection and are very similar. If the lake pipeline is not used, then the higher projections are probably more realistic since there is little motivation for water conservation.

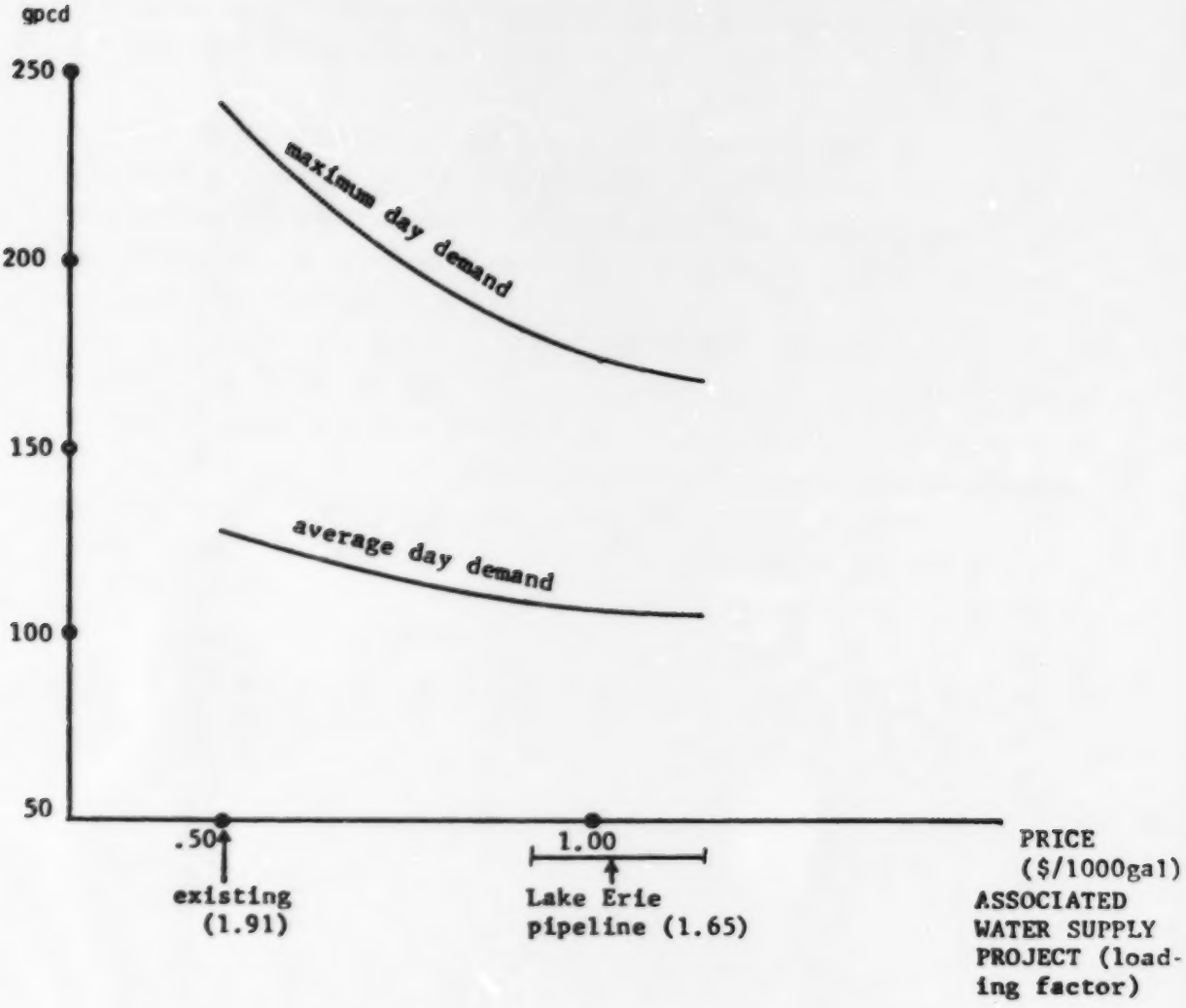
TABLE 2.32

Impact of New Rate Structures on Water Consumption - City of Brantford, 1978

Rate Structure	Existing Increasing Block	Flat Rate	Increasing Block	Seasonal Surcharge	Excess Use
Prices Charged[1] ($/1,000 gal):					
First block (0-44,000 gal/mo)	.55	.49	.26	.38	.48
Second block (44,000-374,000 gal/mo)	.78	.49	.60	.38	.48
Third block (>374,000 gal/mo)	.61	.49	.78	.38	.48
Summer Rate	N/A	N/A	N/A	.80	1.18
Average day Pumpage:					
Total (mgd)	9.94	9.85	10.10	9.74	9.52
Per capita (gpcd)	143	143	146	141	138
Maximum Day Pumpage (mgd):	16.00	17.80	22.25	15.54	14.02
Loading Factor	1.61	1.81	2.20	1.59	1.47

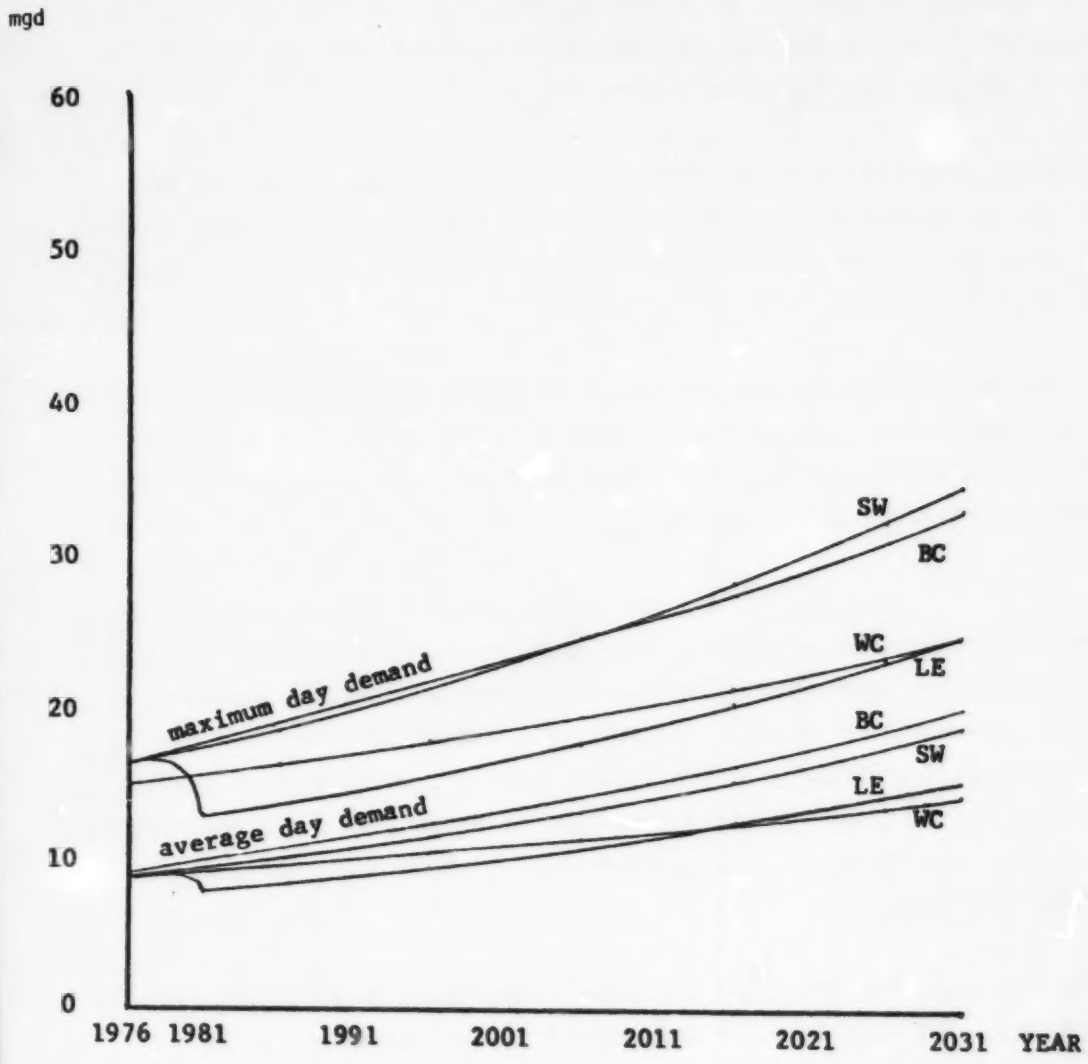
[1]Prices include sewer surcharge. Note that no sewage surcharge is levied on the first block.
N/A - Not applicable.

Figure 2.14 Impact of Price on Per Capita Consumption Rates in the City of Brantford as Supply Costs Increase



NOTE: - A flat rate price structure is assumed. Per capita consumption rates were not significantly affected by the level of population growth unless project costs varied with predicted growth rates.

Figure 2.15 Comparison of Water Demand Projections Using Medium Population Projections for the City of Brantford



LEGEND

BC - Base case with changing housing mix

SW - Pricing based on expanded surface water source

LE - Pricing based on Lake Erie pipeline

WC - Water conservation, low response

2.2.1.5 Summary of Municipal Water Demand Projections for the Major Urban Centres Within the Grand River Basin

Three basic approaches were used in projecting future municipal water demand for the five major urban centres within the Grand River basin. The first approach predicted demand by using existing consumption rates, the second involved assumptions about new conservation measures that could be implemented to reduce consumption, the third modified existing consumption rates to reflect changing water prices.

For summary purposes, 7 projections based on these three approaches were used, the techniques of which are described in Table 2.33. A range in the water consumption rates for the years 2001 and 2031 was produced following these techniques (Table 2.34).

Base case projections for the Cities of Kitchener, Waterloo and Cambridge show per capita rates increasing by up to 5%. This is due to the use of fixed household consumption rates rather than per capita consumption rates to forecast residential consumption.

Forecasts 4 to 7 show average day per capita demand falling by 1% to 30%. The smaller reductions are more likely for Kitchener and Waterloo since these communities have already implemented water conservation programs, a fact not accounted for in these projections. Potential reductions in Cambridge depend critically on the future level of losses (10% of pumpage in 1978). The consumption levels predicted by projection 5 are conceivable in that the associated consumption rates have already been observed in Kitchener and Waterloo.

Consumption rates for Brantford are shown to decrease in all but one of the projections. The high level of consumption in the community can be attributed primarily to industry and losses. Potential savings depend on the scope for adjustment in these two areas. So long as the source of supply, the river, is not considered to be in jeopardy, one may well question the need to reduce consumption in this city. The only real motivation for conservation is financial. In light of this, the base case projecton is probably realistic.

TABLE 2.33

Description of Water Demand Forecasting Methods for the Major Urban Centres Within the Grand River Basin

No.	Main Feature	Population Base	Level of Aggregation of Demand	Source
1	Base Case - demand pro-rated using existing consumption rates	LOW	6 categories treated separately -apartment, residential, commercial, industrial, institutional, losses	Section 2 of this report
2	Base Case - as in Test 1	MEDIUM	as in Test 1	as in Test 1
3	Base Case - as in Test 1	HIGH	as in Test 1	as in Test 1
4	Price sensitive (high) - empirically derived demand curves used to predict response of consumption to anticipated price changes	MEDIUM	forecast based on aggregate community demand	Fortin (1980)
5	Price sensitive (low) - as in Test 4	MEDIUM	as in Test 1	as in Test 1
6	Water conservation (high) - a water conservation program is implemented, moderate residential response is assumed	MEDIUM	as in Test 1	as in Test 1
7	Water conservation (low) - a water conservation program is implemented, maximum residential response is assumed	MEDIUM	as in Test 1	as in Test 1

TABLE 2.34

Estimated Future Consumption Rates for Large Urban Centres, 2001 and 2031

Community - Demand Component	2001							2031						
	Base Case - 1976 Consumption Rates			Price Sensitive Medium Population		Water Conservation Medium Population		Base Case - 1976 Consumption Rates			Price Sensitive Medium Population		Water Conservation Medium Population	
	Low Population	Medium Population	High Population	High Demand Curve	Low Demand Curve	Moderate Response	Maximum Response	Low Population	Medium Population	High Population	High Demand Curve	Low Demand Curve	Moderate Response	Maximum Response
Waterloo														
-Ave. Day														
gpcd	105	105	105	96	88	94	82	105	105	105	100	88	92	79
mgd	9	10	10	8	18	9	8	10	14	16	13	11	12	10
-Max. Day														
gpcd	160	159	159	154	132	138	124	158	153	152	160	131	132	117
mgd	14	15	15	13	12	13	11	15	20	23	21	17	17	15
Kitchener														
-Ave. Day														
gpcd	108	108	108	98	92	97	86	108	108	107	102	93	94	83
mgd	23	24	25	21	21	22	19	25	34	39	32	30	30	26
-Max. Day														
gpcd	159	159	158	157	138	140	127	158	153	151	163	139	132	119
mgd	33	35	37	34	30	31	28	36	49	56	51	43	42	38
Guelph														
-Ave. Day														
gpcd	134	134	134	134	119	109	96	134	133	133	143	119	91	77
mgd	12	16	18	15	14	13	11	17	28	37	29	25	25	21
-Max. Day														
gpcd	231	228	226	214	225	183	168	225	215	211	229	213	150	133
mgd	21	28	30	24	26	22	20	28	45	58	46	45	41	37
Brantford														
-Ave. Day														
gpcd	137	137	137	143	128	112	103	136	136	136	150	128	97	87
mgd	12	13	14	13	12	11	10	16	20	25	21	18	14	13
-Max. Day														
gpcd	238	236	235	229	243	194	180	230	227	224	240	242	170	156
mgd	20	22	25	21	23	18	17	27	33	40	34	35	25	23
Cambridge														
-Ave. Day														
gpcd	121	121	121	111	102	100	87	121	121	121	114	102	93	80
mgd	14	15	18	13	13	12	11	16	22	25	20	18	17	14
-Max. Day														
gpcd	172	172	170	178	153	140	127	172	167	166	182	153	130	116
mgd	20	21	22	21	19	18	16	22	30	34	32	27	23	21

In Guelph, institutional consumption and losses are both high. Household consumption rates also appear to be high. The first four projections show some increase in per capita consumption primarily due to assumptions about family size or industrial growth. Recent rate structure modifications may have already produced some of the savings shown in projections 5, 6 and 7.

Generalizations cannot be made about these projections since consumption characteristics and supply circumstances vary among municipalities. Assuming that the 1978 data is representative, water losses in the municipal system seem to be prominent in three cities: Cambridge, Guelph and Brantford. However, the observed losses are not likely to occur in new distribution systems. This factor will depress future per capita consumption rates. Beyond this, financial and engineering considerations will largely determine the need for and desire for reductions in demand. The radical changes forecast by projection 7 are improbable.

2.2.2 Smaller Urban Centres

To estimate a probable level and range of per capita consumption rates in small communities, a statistical analysis of water consumption in small Ontario communities was undertaken. Data for this analysis were taken from survey information published in the National Inventory of Municipal Waterworks and Wastewater Systems in Canada, 1977 (Canada Supply and Services, 1978). Table 2.35 summarizes the results of this analysis. Measures of standard deviation for all the tests indicate that consumption rates vary widely. Sample data for both average day consumption and maximum day consumption are skewed to the lower end with modal values lying below mean values. Seventy-five percent of average day observations lie between 50 and 175 gpcd (227.28 and 795.47 L/capita d) while 77% of maximum day observations lie between 100 and 350 gpcd (454.56 and 1 590.95 L/capita d.

Consumption characteristics of smaller Grand River basin communities are described in Table 2.36. Mean average day and maximum day figures are close to provincial levels, while the individual figures for each community are well within a "normal" range with the possible exceptions of Elmira and Dunnville. Both of these communities have prominent water consuming

TABLE 2.35

Analysis of Daily Per Capita Water Consumption Rates in Small Ontario Communities

Sample No.	Average Day Per Capita Demand 1	2	3	Maximum Day Per Capita Demand 4	5	6
Population Range	1,000-20,000	1,000-3,000	3,000-10,000	1,000-20,000	1,000-3,000	3,000-10,000
Sample Size	215	110	82	189	96	72
Mean	132	121	142	247	232	265
Mode	113	113	113	175	175	175
Standard Deviation	75	83	63	127	142	111
Maximum Observation	548	548	390	882	882	681
Minimum Observation	24	24	40	27	27	79
Simple Correlatin Between Population and Per Capita Consumption	.079	-.075	.029	.048	-.124	-.033

T-Tests Comparing Mean Values of Daily Per Capita Consumption Rates

Sample No.	(2)	(3)	Sample No.	(5)	(6)
(1)	1.202	1.068	(4)	.902	1.054
(2)		1.906[1]	(5)		1.623[1]

[1]Significant at 90% level.

TABLE 2.36

Municipal Water Supply Data for Smaller Urban Centres
Within the Grand River Basin

Municipality	Consumption (gpcd) Ave. Day/Max. Day	Loading Factor	Reference Year(s)	Population In the Basin	Water Rate Structure
Caledonia	92/191	2.08	1976-1978	3,669	flat rate
Cayuga	121/215	1.77	1976-1978	1,143	flat rate
Dundalk	87/152	1.75	1975-1979	1,130	no information
Dunnville*	192/428	2.23	1976-1978	5,430	declining block rate
Elmira*	236/357	1.51	1976, 1978-79	7,034	declining block rate
Elora	105/152	1.45	1976, 1978-79	2,474	no information
Fergus	104/141	1.36	1976, 1978-79	5,967	domestic-fixed charge, other-declining block
New Hamburg	93/174	1.87	1976-1979	3,628	declining block
Paris	128/215	1.68	1978-1979	6,691	flat rate
Average	104/177 129/225	1.70 1.74		4,129 4,129	

*Both these communities have large industrial users that cause per capita consumption rates to be high.

Sources: Ministry of the Environment, Annual Pumping Reports (1976-1979)
Veale (1980 b)

manufacturers on their systems. The Dunnville manufacturer is a food processor with a highly variable seasonal rate of consumption; this accounts for the high loading factor in that community. When these two towns are omitted from the computation, mean average day and maximum day consumption rates are 104 and 177 gpcd (472.74 and 804.56 L/capita·d) respectively.

Consumption data was either unreliable or unavailable for Arthur, Drayton, Ayr, Grand Valley, Wellesley and Milverton. Many of these communities still rely on private wells for their water supplies. To project demand for these communities, mean consumption rates estimated for small communities other than Dunnville and Elmira were used. Projections for all communities are given in Table 2.37.

2.3 IMPLICATIONS OF MUNICIPAL WATER DEMAND PROJECTIONS

When comparing possible future water consumption figures generated by the preceding analyses to the available water source capacities of each municipality on a municipal water supply system, possible water shortage areas can be identified.

Table 2.1 indicates the 1979 water source capacity for municipalities on a municipal water supply system. Tables 2.38 and 2.39 show average and maximum daily water demands respectively, for the 5 major urban centres based on the 7 projections selected. In municipalities where: (1) supply systems are designed to accommodate maximum day needs, (2) sufficient water storage is available, and (3) there is enough water available for continuous extraction to meet average day demand, water shortages will not be experienced.

By comparing average and maximum daily water demands to 1979 system capacities, it is evident that water shortages could be felt in all major cities (with the exception of Brantford where projected water demand should be met by water extracted from the Grand River), by the year 2031 if no conservation measures or new pricing structures were implemented. Additional water supplies will be necessary to meet demand before 2001 for the Cities of Kitchener and Waterloo. The time at which these new supplies

TABLE 2.37

Projections of Water Demand for Smaller Municipalities in the Grand River Basin

Municipality	Year 1979	2001 Low	2001 Medium	2001 High	2031 Low	2031 Medium	2031 High
Average Day Demand (1,000's gpd)							
Fergus	621	885	1,158	1,371	1,204	2,372	3,329
Paris	856	1,024	1,126	1,214	1,102	1,398	1,686
Caledonia	338	598	897	1,196	1,196	1,456	1,716
Dunnville	1,043	1,364	1,380	1,467	1,833	2,012	2,320
Elmira	1,660	2,053	2,188	2,277	2,259	3,141	3,612
New Hamburg	337	422	449	468	464	645	742
Elora	260	401	467	561	675	945	1,362
Cayuga	138	145	224	302	302	368	434
Ayr	138	223	237	247	245	341	392
Drayton	85	108	123	157	146	192	329
Dundalk	98	136	161	182	195	291	382
Grand Valley	110	159	181	222	248	328	513
Wellesley	88	152	162	168	167	232	267
Arthur	169	212	229	246	263	324	384
Milverton	73	79	107	153	87	169	371
Maximum Day Demand (1,000's gpd)							
Fergus	841	1,199	1,570	1,859	1,632	3,216	4,513
Paris	1,439	1,720	1,892	2,039	1,851	2,348	2,831
Caledonia	701	1,241	1,862	2,483	2,483	3,023	3,562
Dunnville	2,324	3,040	3,076	2,369	4,085	4,485	5,171
Elmira	2,511	3,106	3,310	3,444	3,418	4,751	5,465
New Hamburg	631	789	841	875	868	1,207	1,388
Elora	376	580	676	812	976	1,367	1,971
Cayuga	246	258	398	537	537	654	771
Ayr	236	379	404	421	417	580	667
Drayton	144	184	209	267	249	326	560
Dundalk	172	237	282	318	340	509	668
Grand Valley	188	271	308	377	422	558	873
Wellesley	149	259	276	287	285	396	455
Arthur	288	361	389	418	448	551	653
Milverton	124	134	182	260	147	288	631

TABLE 2.38

Additional Municipal Water Supply Necessary to Meet Average Day Projected Demand*, 2001 and 2031
(mgd)

Water Demand Projections / Community	2001							2031						
	Base Case			Price Sensitive Medium Population		Water Conservation Medium Population		Base Case			Price Sensitive Medium Population		Water Conservation Medium Population	
	Low Population	Medium Population	High Population	High Demand Curve	Low Demand Curve	Moderate Response	Maximum Response	Low Population	Medium Population	High Population	High Demand Curve	Low Demand Curve	Moderate Response	Maximum Response
Kitchener-Waterloo														
System Capacity = 32.648														
Ave. Day Demand (1977) = 18.18	31.63	33.70	35.07	30.65	28.58	30.24	26.69	34.80	48.37	55.27	45.90	41.34	42.18	36.95
Additional Supplies Needed	--	.95	2.42	--	--	--	--	2.15	15.73	22.62	13.15	8.69	9.54	4.30
Guelph														
System Capacity = 25.81														
Ave. Day Demand (1977) = 9.50	12.09	15.47	17.48	15.67	13.74	12.58	11.08	16.10	27.81	36.40	29.91	24.89	19.03	16.10
Additional Supplies Needed	--	--	--	--	--	--	--	--	2.00	10.59	4.10	--	--	--
Brantford														
System Capacity = 17.50														
Ave. Day Demand 1977 = 9.67	12.29	13.60	15.04	14.19	12.70	11.11	10.22	16.44	20.54	25.65	22.66	19.33	14.65	13.14
Additional Supplies Needed	--	--	--	--	--	--	--	--	3.04	8.15	5.16	1.83	--	--
Cambridge														
System Capacity = 16.99														
Ave. Day Demand (1977) = 8.58	14.13	15.06	15.67	13.92	12.70	12.45	10.83	15.55	21.62	24.86	20.37	18.22	16.62	14.29
Additional Supplies Needed	--	--	--	--	--	--	--	--	4.63	7.87	3.38	1.23	--	--

*Refers to supplies which would be necessary to meet demand after the 1979 Source capacity is fully utilized.

**Demand for the City of Brantford is expected to be met wholly through extraction of river water.

TABLE 2.19

Additional Municipal Water Supply Necessary to Meet Projected Maximum Day Demand*, 2001 and 2031
(mgd)

Community / Water Demand Projections	2001							2031						
	Base Case			Price Sensitive Medium Population		Water Conservation Medium Population		Base Case			Price Sensitive Medium Population		Water Conservation Medium Population	
	Low Population	Medium Population	High Population	High Demand Curve	Low Demand Curve	Moderate Response	Maximum Response	Low Population	Medium Population	High Population	High Demand Curve	Low Demand Curve	Moderate Response	Maximum Response
Kitchener-Waterloo														
System Capacity = 32.648														
Max. Day Demand (1977) = 29.08	47.032	50.024	51.822	49.118	42.864	43.862	39.680	51.327	69.091	76.581	73.210	61.711	59.608	53.473
Additional Supplies Needed	14.384	17.376	19.174	16.470	10.216	11.214	7.032	18.679	36.443	43.933	40.562	29.063	26.96	20.825
Guelph														
System Capacity = 25.81														
Max. Day Demand (1977) = 13.10	20.85	26.32	29.49	24.71	25.98	21.13	19.40	27.37	44.96	57.74	47.89	44.55	31.37	27.81
Additional Supplies Needed	--	.51	3.68	--	.17	--	--	1.56	19.15	31.93	22.08	18.74	5.56	2.00
Brantford**														
System Capacity = 17.50														
Max. Day Demand (1977) = 16.12	21.34	23.42	25.80	22.73	24.11	19.25	17.86	27.80	34.29	42.24	36.25	36.55	25.68	23.56
Additional Supplies Needed	3.84	5.92	8.30	5.23	6.61	1.75	.33	10.3	16.79	24.74	18.75	19.05	8.18	6.06
Cambridge														
System Capacity = 16.99														
Max. Day Demand (1977) = 12.87	20.09	21.41	22.02	22.16	19.04	17.43	15.81	22.11	29.84	34.11	32.52	27.34	23.23	20.72
Additional Supplies Needed	3.10	4.42	5.03	5.17	2.05	.44	--	5.12	12.85	17.12	15.53	10.35	6.24	3.73

*Refers to supplies which would be necessary to meet demand after the 1979 Source capacity is fully utilized.

**Demand for the City of Brantford is expected to be met wholly through extraction of river water.

will be required is dependent on population growth and water conservation practices. The City of Guelph will require new water supplies by 2031 if population growth equals the medium or high population projections and no conservation methods are adopted.

Water demand in the smaller municipalities of the watershed was estimated using mean average day and maximum day consumption rates of 104 and 177 gpcd (472.74 and 804.56 L/capita·d) respectively and applying these rates to future projected populations. Two communities may experience water shortages by the year 2031. Elora is expected to experience shortages if the projected low population were reached while Fergus is expected to require more supplies if the medium population projection were realized.

3. INDUSTRIAL WATER DEMAND FROM PRIVATE WATER SOURCES

3.1 EXISTING WATER USE

Many industries within the Grand River basin obtain water from private surface or ground-water sources. Of 65 industries which obtained approval from the Ontario Ministry of the Environment between 1963-1980, 55 or 85% were allowed to extract ground water from wells or dugout ponds. Most of the remaining industries were associated with the mineral aggregate business and permitted to use surface water for washing and dust control (Appendix D).

To determine whether or not actual water demand by industries approximates permitted use, a sample telephone survey of the 75% of the industries using private water sources in the Middle Grand River sector (the sector of largest industrial water consumption) was conducted during the fall, 1980. Most industries reported that actual water use approximated that which was authorized by permit.

To estimate actual total water demand, the daily rates recorded in the water taking permits were multiplied by the recorded number of days the industry extracted water. These estimates were adjusted to account for industries no longer in operation or using private water supply systems. Where daily and yearly rates of water use were reported to differ from those recorded on water taking permits, the figures quoted by the industry during the telephone survey were assumed to be correct (Table 3.1).

3.2 FUTURE WATER DEMAND

Future water needs of industries not supplied by a municipal water system were estimated based on past trends.

A high correlation between population and permitted industrial water takings between the years 1963-1976 was found through regression analysis. By taking the natural logarithm of the population change and relating it to permitted industrial water takings for two year intervals, a semi-logarithmic curve fit was obtained, with a correlation co-efficient of

TABLE 3.1

Water Use By Industries Not Supplied by Municipal Water Supply Systems, 1980

Sub-Basin Sector	Type of Water Use: Dewatering mgd	Dewatering mg/yr	Aggregate Washing mgd	Aggregate Washing mg/yr	Sanitary mgd	Sanitary mg/yr	Cooling mgd	Cooling mg/yr	Industrial Processing mgd	Industrial Processing mg/yr	Food Processing mgd	Food Processing mg/yr	Miscellaneous mgd	Miscellaneous mg/yr	Total mgd	Total mg/yr	% of Total Water Use by Sub-Basin Sector	
Lower Grand River	5.74	1666.0	3.26	728.0	.01	3.3	.22	55.1	.11	25.9	.15	45.3	.28	101.5	9.77	2625.1	30.2	31.2
Whitemon Creek													.11	27.0	.11	27.0	.3	.3
Mith River			1.94	471.1	.20	58.7	.08	26.2			1.64	562.7	.14	52.6	4.00	1171.3	12.3	13.9
Paris			1.92	468.5											1.92	468.5	5.9	5.6
Middle Grand River			8.17	1712.4	.20	69.0	4.12	1337.4	.46	123.6	.52	187.3	.03	10.6	13.50	3440.3	41.8	40.9
Conestogo			2.70	567.0	.02	6.1	.04	15.8	.23	84.1			.08	16.0	3.07	689.0	9.5	8.1
Upper Grand River																		
Total	5.74	1666.0	17.99	3947.0	.43	137.1	4.46	1434.5	.80	233.6	2.31	795.3	.64	207.7	32.37	8921.2	100	100
% of Total Water Use By Type	17.7	19.8	55.6	46.8	1.3	1.6	13.8	17.0	2.5	2.8	7.1	9.4	2.0	2.6	100	100		
% Ground Water	100	100	34.7	36.2	97.7	99.9	96.4	99.3	86.5	88.9	100	100	100	100	62.9	69.3		
% Surface Water	--	--	65.3	63.8	2.3	0.1	3.6	0.7	13.5	11.1	--	--	--	--	37.1	30.7		

0.78. Assuming that this relationship continues to the year 2031, a range in the amount of water needed in the future was predicted based on low, medium and high population projections.

Estimations of industrial water demand for each sub-basin sector were determined by assuming that the type and distribution of future industries would remain the same as existed in 1978 with the exception of the Middle Grand River sector.

Since almost half of the water extracted for industrial use in 1978 was taken from surface and ground-water sources within the Middle Grand River sector, future industrial water needs were estimated at a more detailed level for the major municipalities in this area.

In 1978, industries within Kitchener extracted 22.7% of the total daily water takings calculated for the Middle Grand River sector while 12.6%, 15.4%, and 49.3% of the total daily water takings were extracted by industries within Waterloo, Cambridge and Guelph respectively.

To estimate a realistic range for water demand, two assumptions were used: (1) the type and distribution of future industries and the industrial water sources for these industries will remain the same as existed in 1978, and (2) those industries extracting ground water within the municipal boundaries of the Cities of Kitchener, Waterloo and Cambridge will not be allowed in the future to extract more water than is currently permitted and newly established industries will be linked to the municipal water supply system. The remaining industries which extract surface water will continue to expand as predicted by the regression analysis. The second assumption is considered to be the most realistic for cities within the Regional Municipality of Waterloo since water managers are already closely scrutinizing water use and advocating that new industries be linked to a municipal supply system. Tables 3.2 and 3.3 outline the daily and yearly ranges in ground and surface water demand based on the above assumptions for the Cities of Kitchener, Waterloo, Cambridge and Guelph for the years 2001 and 2031. The estimated range in industrial water demand for each sub-basin sector is illustrated in Table 3.4.

TABLE 3.2

Estimated Daily Industrial Water Demand From Private Sources for Kitchener, Waterloo, Cambridge and Guelph, 2001 and 2031

Municipality	Existing Water Demand (mgd) Surface Water	Ground Water	Total	Estimated Surface Water Demand (mgd) 2001	Estimated Ground Water Demand (mgd) 2001	Total Water Demand (mgd) 2001	Estimated Surface Water Demand (mgd) 2031	Estimated Ground Water Demand (mgd) 2031	Total Water Demand (mgd) 2031
Kitchener	0.60	2.466	3.066	1.1 - 1.3	2.5 - 5.2	3.6 - 6.5	1.6 - 2.1	2.5 - 8.4	4.1 - 10.5
Waterloo	--	1.690	1.690	-- --	1.8 - 3.6	1.8 - 3.6	-- --	1.8 - 5.8	1.8 - 5.8
Cambridge	--	2.089	2.089	-- --	2.1 - 4.4	2.1 - 4.4	-- --	2.1 - 7.2	2.1 - 7.2
Guelph	2.208	4.46	6.668	4.3 - 4.7	8.6 - 9.4	12.9 - 14.1	5.9 - 7.6	11.9 - 15.3	17.8 - 22.9
Total	2.808	10.705	13.513	5.4 - 6.0	15.0 - 22.6	20.4 - 28.6	7.5 - 9.7	18.3 - 36.7	25.8 - 46.4

TABLE 3.3

Estimated Yearly Industrial Water Demand From Private Sources for Kitchener, Waterloo, Cambridge and Guelph

Municipality	Existing Water Demand (mg/yr) Surface Water	Ground Water	Total	Estimated Surface Water Demand (mg/yr) 2001	Estimated Ground Water Demand (mg/yr) 2001	Total Water Demand (mg/yr) 2001	Estimated Surface Water Demand (mg/yr) 2031	Estimated Ground Water Demand (mg/yr) 2031	Total Water Demand (mg/yr) 2031
Kitchener	111.00	793.40	904.40	213.3 - 234.6	793.4 - 1,677.0	1,006.7 - 1,911.6	297.0 - 380.6	793.4 - 2,720.7	1,090.4 - 3,101.3
Waterloo	--	564.62	564.62	-- --	582.3 - 1,202.2	582.3 - 1,202.2	-- --	593.5 - 1,950.4	593.5 - 1,950.4
Cambridge	--	397.39	397.39	-- --	397.4 - 840.0	397.4 - 840.0	-- --	397.4 - 1,362.8	397.4 - 1,362.8
Guelph	437.52	1,136.58	1574.10	840.7 - 924.8	2,183.9 - 2,402.3	3,024.6 - 3,327.1	1,170.6 - 1,500.3	3,040.6 - 3,897.6	4,211.2 - 5,397.9
Total	548.52	2,891.99	3,440.51	1,054.0 - 1159.4	3,957.0 - 6,121.5	5,011.0 - 7,280.9	1,467.6 - 1,880.9	4,824.9 - 9,931.5	6,292.5 - 11,812.4

TABLE 3.4

Future Water Demand Estimates for Industries Not Supplied by Municipal Water Supply Systems

Sub-Basin Sector	Existing Water Demand mgd (mg/yr)	% Groundwater Source mgd (mg/yr)	Estimated Range for Water Demand 2001 mgd (mg/yr)	Estimated Range for Water Demand 2031 mgd (mg/yr)
Lower Grand River	9.8 (2,625)	92 (89)	19.0 - 20.8 (5,139 - 5,626)	26.5 - 33.9 (7,167 - 9,169)
Whiteman Creek	0.1 (27)	100 (100)	0.2 - 0.2 (54 - 54)	0.3 - 0.3 (81 - 81)
Nith River	4.0 (1,171)	52 (60)	7.5 - 8.2 (2,151 - 2,352)	10.4 - 13.4 (2,983 - 3,844)
Paris and Middle Grand River	15.4 (3,909)	46 (54)	24.0 - 32.7 (5,889 - 8,281)	30.9 - 53.0 (7,537 - 13,422)
Conestogo River	3.1 (689)	100 (100)	6.0 - 6.6 (1,333 - 1,467)	8.3 - 10.6 (1,845 - 2,356)
Upper Grand River	0	-- --	-- -- -- --	-- -- -- --
Total	32.4 (8,421)	63 (69)	56.7 - 68.5 (14,566 - 17,780)	76.4 - 111.2 (19,613 - 28,872)

3.3 IMPLICATIONS OF INDUSTRIAL WATER DEMAND PROJECTION

The projections for industrial water consumption for those industries with private water supplies indicate that the critical areas where existing water supply may become insufficient to meet demand are in the central basin, specifically in the Cities of Kitchener, Waterloo, Cambridge and Guelph. For these four municipalities, an increase in ground-water demand from 40% to 111% is projected by the year 2001. Concurrently, surface water demand is expected to more than double in Kitchener and Guelph.

If the low estimate for industrial water demand is realized, adequate water supplies will be available in the central basin to meet industrial needs. Since the low estimate represents a situation where no new demand for ground-water supplies will occur in the Cities of Kitchener, Waterloo and Cambridge, a further increase in abstraction of ground water for industrial purposes would affect the availability of water for municipal use requiring the implementation of water supply projects before they would otherwise be needed.

4. AGRICULTURAL WATER DEMAND

4.1 IRRIGATION

4.1.1 Existing Water Use

Water withdrawal for irrigation of field crops such as tobacco, vegetables and other market garden crops is authorized by permit by the Ontario Ministry of the Environment and represents a significant portion of total permitted water takings within the Grand River basin (Appendix E)*. Demand for irrigation occurs primarily in the tobacco growing areas. In 1978, approximately 85% of all authorized water takings were issued in the watersheds of Whiteman Creek, Mt. Pleasant Creek and McKenzie Creek. Total demand in these areas was estimated by means of a telephone survey at 230, 103, and 73 million gallons per season** (1 045 000, 468 190 and 331 830 m^3/season) respectively (Frigon, 1979). To estimate the number of days of irrigation during the season for these watersheds, it was assumed that the maximum daily withdrawal of water approximates the daily rate of withdrawal authorized by permit. In order to meet total demand per season, it was calculated that, on the average, a total of 5 days of continuous irrigation was necessary, distributed over two or three applications.

To determine total water demand per season within the entire basin during 1978, it was assumed that irrigation practices were similar in other sub-basins where irrigation was authorized by permit. By multiplying total water takings (mgd) allowed for each sub-basin by the average number of days per season required for irrigation as calculated above, total water demand was estimated (Table 4.1).

4.1.2 Future Water Demand

To predict future water needs for irrigation throughout the Grand River basin, two basic assumptions were made:

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* Appendix E has been updated to September 1982. Calculations for water demand for irrigation purposes are based on permitted water takings to December 1978.

** A season refers to the 92 day period between June and August.

TABLE 4.1

Existing and Estimated Irrigation Needs for Row Crops*, 2001 - 2031

Basin Sector	Existing Water Demand (mg) (1978)	Scenario 1 Estimated Water Demand (mg) 2001	Scenario 1 Estimated Water Demand (mg) 2031	Scenario 2 Estimated Water Demand (mg) 2001	Scenario 2 Estimated Water Demand (mg) 2031	Scenario 3 Estimated Water Demand (mg) 2001	Scenario 3 Estimated Water Demand (mg) 2031	Scenario 4 Estimated Water Demand (mg) 2001	Scenario 4 Estimated Water Demand (mg) 2031
Upper Grand River	--	50.72	84.54	50.72	75.56	50.72	84.54	22.83	22.83
Conestogo River	--	58.89	82.71	36.41	52.34	58.89	82.71	30.48	30.48
Middle Grand River	11.12	577.26	602.77	483.31	484.25	515.16	575.71	224.50	224.50
Paris	44.97	13.97	13.97	12.15	12.15	13.97	13.97	11.21	11.21
Nith River	268.70	539.65	613.63	470.86	539.78	451.83	547.14	311.09	311.09
Whiteman Creek	161.73	384.29	384.29	326.31	326.31	384.22	384.29	237.68	237.68
Lower Grand River	486.62	212.27	222.28	199.91	207.00	187.98	208.75	94.15	94.15
Total Water Demand		1837.05	2004.19	1579.67	1697.39	1662.77	1897.11	931.94	931.94
Additional Water Demand Above 1978 level (MG)		1350.43	1517.56	1093.04	1210.76	1176.14	1410.48	445.31	445.31

*Calculated for a 92 day period from June to August.

1. Any irrigation that would take place within the basin would be on sandy and sandy loam soils in which row crops are grown (Ayers, 1980).

2. Water would be applied to an area of corn at a rate of 1 inch per application and an area of other row crops at a rate of .85 inches per application, assuming three applications per season (June-August) (Brown, 1980).

To determine the area of row crops which might be grown on sandy and sandy loam soils in the future the following methodology was used:

1. The percentage of each sub-basin within the watershed exhibiting sandy and sandy loam soils was estimated with the aid of soil survey documents.

2. It was assumed that the distribution of row crops and sandy and sandy loam soils would be homogeneous throughout a particular sub-basin.

3. The area of sandy and sandy loam soils in row crops was calculated by assuming that the proportion of sandy and sandy loam soils within a particular sub-basin would be similar to the proportion of sandy and sandy loam soils within an area planted in row crops. For example, if 10% of a particular sub-basin consisted of sandy and sandy loam soils, 10% of the area of row crops would be planted in sandy and sandy loam soils.

4. The future area of row crops was given as estimated in Technical Report No. 8 "Existing and Future Land Use Activities Within the Grand River Basin" (Veale, 1980 a).

Although it is acknowledged that the above assumptions may not be realistic, it is felt that the given methodology provides a "ball park" estimate of the area of row crops in sandy and sandy loam soils within a particular sub-basin. Information and time constraints precluded a more in-depth analysis.

Technical Report No. 8 outlines four scenarios which provide a range for the future area and distribution of row crops. The amount of irrigation needed for each sub-basin varies according to the particular scenario used.

To predict water needs for each sub-basin, the area of row crops in sandy and sandy loam soils was calculated for each scenario and the amount of irrigation required was determined by assuming three applications of water of 1 inch (25.4 mm) over the projected area of corn and .85 inch (21.59 mm) over the projected area of other row crops.

Results are given in millions of gallons per season for the sub-basins delineated in Figure 1.1. Total additional water demand after 1978 was calculated by subtracting the 1978 demand from the projected total water demand (Table 4.1; Appendix F; and Tables F1.1 to F1.4).

4.1.3 Implications of Irrigation Water Demand Projections

Since over 88% of the water extracted for crop irrigation is from surface sources, the following methodology was used to estimate whether or not there is enough available surface water to meet projected irrigation needs.

Statistics detailing the mean flow experienced during the months of June, July and August were collected from surface water records for seven gauging stations: Grand River near Marsville (GA14); Conestogo River at Drayton (GA17); Canagagigue Creek near Elmira (GA23); Speed River above Guelph (GA20); Eramosa River above Guelph (GA29); Nith river near Canning (GA10); and Whiteman Creek near Mount Vernon(GB8). At least 12 consecutive years of flow data were used to calculate the probability of non-exceedance for summer run-off at each gauging station with the exception of the gauge above Guelph on the Speed River where only 8 years of data were available. These data were plotted on log probability paper and run-off equivalents to 50, 10 and 5 percent probability of non-exceedance were estimated. Table 4.2 indicates the inches of run-off estimated for the 50, 10 and 5 percent probability of non-exceedance levels for the seven gauging stations.

To determine the run-off equivalents at the selected probability levels for each sub-basin, two factors were taken into consideration; the run-off equivalents calculated at the nearest downstream gauging station and the drainage characteristics relative to each sub-basin. Those sub-basins with corresponding drainage characteristics adjacent to a sub-basin for which run-off equivalents were estimated, were assigned the same run-off equivalents. However, in the case of the sub-basin below Guelph on the Speed River, the most relevant run-off equivalents were considered to be those estimated for Whiteman Creek since drainage characteristics of the two areas are similar, (Figure 4.1; and Table 4.2).

Supply of surface water for each sub-basin in millions of gallons for the summer months (June-August) was calculated by multiplying the run-off equivalents for the probability levels chosen, by the sub-basin drainage area.

Assuming that the majority of irrigable crops are distributed in the middle and lower areas of the sub-basins, results indicate that there is more than enough surface water available for irrigation spread over the three month period. Table 4.3 shows that with a 95% probability of run-off being exceeded (or a .05% probability of run-off not being exceeded), there is an adequate supply of surface water for each sub-basin sector. However, some water storage may be required if water were needed for irrigation in more than one application during a specific month under maximum water demand conditions in two sub-basins; the Conestogo River below the Conestogo Dam, and the Speed River above Guelph.

4.2 LIVESTOCK

4.2.1 Existing Water Use for Livestock

In addition to water uses related to irrigation, water is also consumed in significant quantities by livestock. The water consumed by livestock is not included under water permits for irrigation but is extracted from private domestic wells or surface sources such as streams and/or farm ponds. The water used by livestock was estimated for the year 1976 by

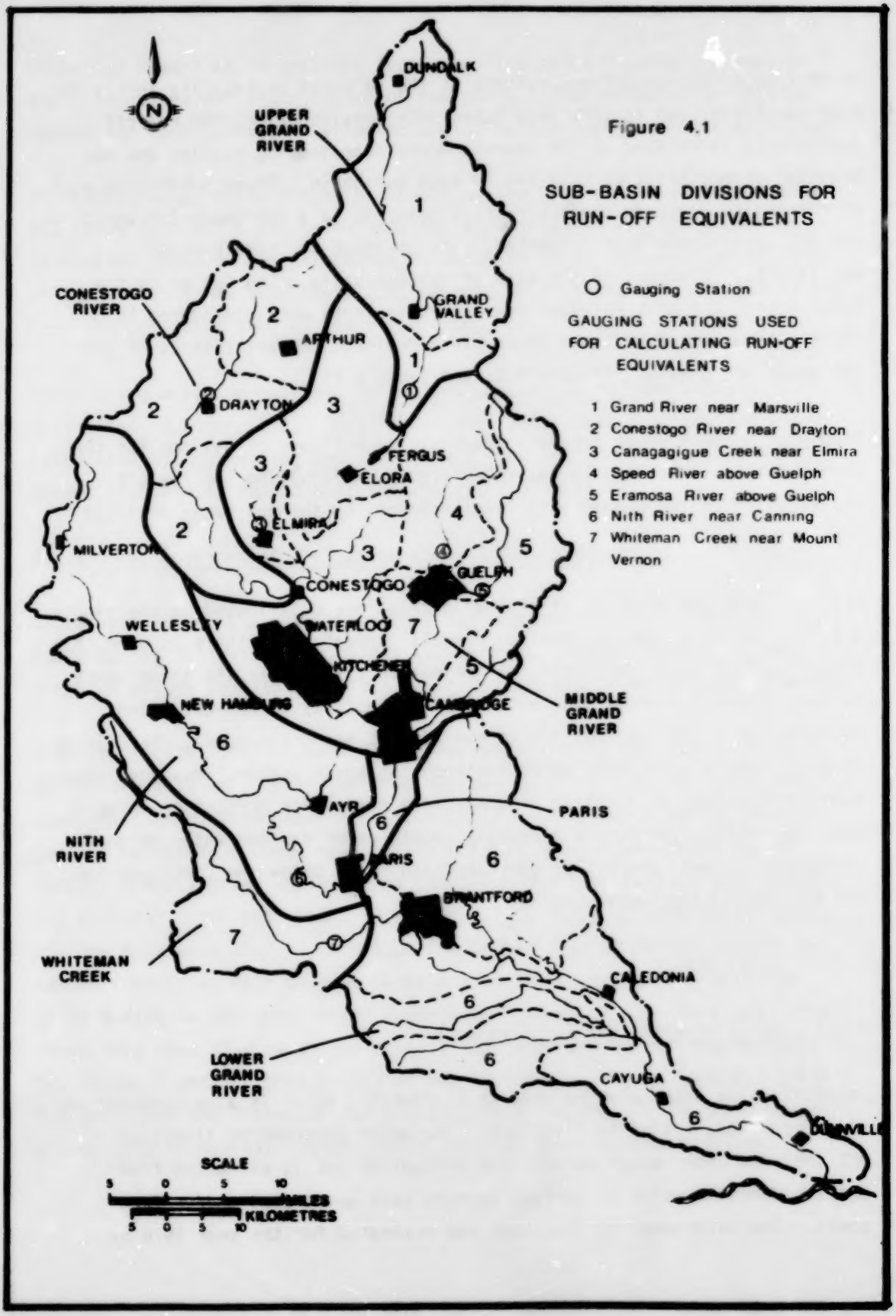


Figure 4.1
SUB-BASIN DIVISIONS FOR RUN-OFF EQUIVALENTS
Gauging Station
GAUGING STATIONS USED FOR CALCULATING RUN-OFF EQUIVALENTS
1 Grand River near Marsville
2 Conestogo River near Drayton
3 Canagagigue Creek near Elmira
4 Speed River above Guelph
5 Eramosa River above Guelph
6 Nith River near Canning
7 Whiteman Creek near Mount Vernon
UPPER GRAND RIVER
CONESTOGO RIVER
MIDDLE GRAND RIVER
NITH RIVER
WHITEMAN CREEK
LOWER GRAND RIVER
DUNDALK
GRAND VALLEY
ARTHUR
DRAYTON
FERGUS
ELORA
ELMIRA
MILVERTON
CONESTOGO
GUELPH
WELLESLEY
WATERLOO
KITCHENER
CAMBRIDGE
NEW HAMBURG
AYR
PARIS
BRANTFORD
CALEDONIA
CAYUGA
SCALE
MILES
KILOMETRES

TABLE 4.2

Estimated Inches of Run-Off at 50, 10 and 5 Percent Probability of Non-Exceedance

Gauging Station	Drainage Area	Inches of Run-Off % Probability of Non-Exceedance (June-August) .50	.10	.05
GA14 - Grand River near Marsville	268 Sq. Miles	.80	.40	.28
GA17 - Conestogo River at Drayton	125 Sq. Miles	.40	.07	.065
GA23 - Canagagigue Creek near Elmira	45.4 Sq. Miles	1.09	.33	.28
GA20 - Speed River above Guelph	104 Sq. Miles	1.33	.28	.24
GA29 - Eramosa River above Guelph	91 Sq. Miles	1.43	.99	.97
GA10 - Nith River near Canning	398 Sq. Miles	1.20	.75	.65
GB8 - Whiteman Creek near Mount Vernon	148 Sq. Miles	1.00	.70	.65

TABLE 4.3

Estimated Agricultural Irrigation Water Demand and Surface Water Supply

Sector	Associated Sub-Basins	Total Area of Sector (ha)	Estimated Maximum Water Demand (mg) 2001	2031	Estimated Supply (mg) Probability of Flow Being Exceeded .50	.90	.95
Upper Grand River							
a) Grand River above Lake Belwood	GA0101; GA0102	68 898	19.80	34.72	3,064	1,532	1,073
b) Grand River above Shand Dam	GA0103	13 400	30.92	49.82	596	298	208
Total		82 298	50.72	84.54	3,660	1,830	1,281
Conestogo River							
a) Conestogo River above Conestogo Lake	GA0601	27 707	7.02	12.22	616	108	100
b) Conestogo River above Conestogo Dam	GA0602	28 829	14.45	25.18	633	112	104
c) Conestogo River below Conestogo Dam	GA0603; GA0604	26 562	37.42	45.31	488	103	96
Total		83 098	58.89	82.71	1,737	323	300
Middle Grand River							
a) Grand River above West Montrose	GA0104	36 752	124.34	143.51	2,227	674	572
b) Canagagigue Creek	GA0105; GA0106	10 761	30.44	30.44	651	197	168
c) Speed River above Guelph	GA0401; GA0402	27 853	341.54	341.54	2,060	434	372
d) Speed River below Guelph	GA0403; GA0404; GA0405; GA0406; GA0407; GA0408	22 977	54.14	54.14	1,276	893	830
e) Eramosa River above Guelph	GA05	26 505	25.25	32.27	2,107	1,459	1,429
f) Galt Creek	GA0301; GA0302; GA0303; GA0304	9 926	1.55	1.55	789	541	535
g) Grand River above Cambridge	GA0107; GA0108; GA0109; GA0110	50 973	--	--	3,091	936	794
Total		185 747	577.26	603.45	12,201	5,134	4,700
Paris	GA0111	9 617	13.97	13.97	641	401	348
Nith River	GA0201; GA0202; GA0203; GA0204; GA0205; GA0206; GA0207; GA0208; GA0209; GA0210	114 617	539.65	613.63	7,648	4,780	4,142
Whiteman Creek	GB0501; GB0502	40 754	384.29	384.29	2,265	1,586	1,473
Lower Grand River							
a) Fairchild and Big Creek	GB04; GB03	58 878	22.13	22.13	3,843	2,402	2,128
b) McKenzie Creek	GB0201	20 297	60.50	60.60	1,354	846	734
c) Boston Creek	GB0202	23 083	28.04	36.08	1,540	963	834
d) Grand River below Brantford	GB0101; GB0102; GB0103	78 877	101.60	112.73	5,262	3,289	2,050
Total		181 135	212.27	234.54	11,999	7,500	6,546
Total Watershed		696 466					

assuming that milk and other cows consume an average of 40 and 15 gallons (181.84 and 68.19 L) of water per day respectively while sheep and pigs consume 2 gallons (9.09 L) per day (Frigon, 1979) (Appendix G; and Table G1.1).

4.2.2 Future Water Demand by Livestock

Two projections of the future number of animal units within the watershed to the year 2031 are given in Technical Report No. 8 (Veale, 1980 a). One scenario assumes that the change in animal units within each sub-basin sector will follow past trends. The second scenario assumes that the number and distribution of animal units will remain relatively unaltered in the future. Since the second scenario predicts a "no change" situation, minimum future water demand is expected to remain at the 1976 level. To predict the number of cattle, sheep and pigs which may be raised within the basin, according to the first scenario it was assumed that the 1976 proportion of animal units from each livestock type would remain stable to the year 2001. These projections are outlined in Appendix G, Table G1.1, G1.2 and G1.3.

Assuming that the average daily consumption rates remain the same for each livestock type, an estimate of future water demand for livestock was derived as given in Table 4.4 by sub-basin sector.

4.2.3 Implications of Livestock Water Demand

The projected increase in the amount of water needed for livestock consumption is approximately 1.432 million gallons (6 509.24 m^3) by the year 2001 and 3.223 million gallons (14 650.33 m^3) by the year 2031. Significant increases may occur in three sub-basins - the Nith, Middle Grand and Conestogo - however, water shortages are not anticipated.

TABLE 4.4

Livestock Water Demand in the Grand River Basin, 1976, 2001 and 2031

Sub-Basin Sector	Estimated Livestock Water Demand, 1976 (gpd)	Estimated Livestock Water Demand, 2001 (gpd)	Estimated Livestock Water Demand, 2031 (gpd)
Lower Grand River	1,265,098	365,910	365,910
Whiteman Creek	443,801	452,160	352,904
Nith River	1,891,482	2,650,324	3,076,728
Paris	98,337	99,194	89,413
Middle Grand River	1,545,861	2,828,085	3,717,265
Conestogo River	1,762,739	1,981,580	2,566,692
Upper Grand River	690,712	753,006	753,006
Total	7,698,030	9,130,259	10,921,918

5. OTHER WATER DEMAND

Existing and future water demand for the primary water users within the basin has been outlined in previous chapters. Further demand is placed on water resources for rural domestic, commercial and recreational activities. The nature and extent of this demand and its implications for future water management are outlined in the following sections.

5.1 RURAL DOMESTIC

While the majority of the basin population is serviced by municipal water supply systems, the remaining 19% obtains water from private sources, primarily wells. In the Lower Grand River sector, a limited number of residents supplement well water (used mostly for drinking) with rain water collected in cisterns (used mainly for washing).

The daily water demand by the unserviced rural population in the basin was estimated by the Ontario Ministry of the Environment in 1978, based on water taking permit records. The average per capita consumption rate ranged between 49 and 51 gallons per day (222.73 L/day, 231.82 L/day). Total water use for rural domestic purposes was estimated at 5.583 mgd (25.37 m^3 x10^3) or 2,038 mg/yr (9 262.94). Rural domestic water use by sub-basin sector is outlined in Table 5.1.

Future domestic water demand was estimated using the assumption that average per capita consumption rates will remain stable between the years 1978 and 2031. A range in future demand by sub-basin sector was obtained by multiplying the projected populations outlined in Table 2.6 by an average per capita consumption rate of 50 gallons per day (227.28 L/day) (Table 5.1).

The projected increase in rural domestic water demand is between 0.621 and 2.499 mgd (2 822.8 and 11 359.3 m^3/d) by the year 2001 and 1.476 and 7.888 mgd (6 709.2 and 35 855.4 m^3/d) by the year 2031. Increases in demand are expected in all sub-basins. No water shortages are anticipated to the year 2031.

TABLE 5.1

Rural Domestic Water Demand Estimates

Sub-Basin Sector	Estimated Water Demand (mgd), 1978	Estimated Water Demand (mgd), 2001				Estimated Water Demand (mgd), 2031			
		Low Low Proj.	Low Proj.	Med. Proj.	High Proj.	Low Low Proj.	Low Proj.	Med. Proj.	High Proj.
Upper Grand River	.322	.333	.333	.496	.635	.432	.432	.873	1.371
Conestogo River	.696	.766	.790	.915	1.052	.933	.941	1.399	1.958
Middle Grand River	1.649	1.728	1.790	2.053	2.357	2.091	2.110	3.091	4.320
Paris	.115	.120	.127	.138	.149	.134	.136	.183	.221
Nith River	1.035	1.095	1.158	1.267	1.374	1.274	1.293	1.746	2.137
Whiteman Creek	.348	.388	.388	.436	.493	.431	.431	.558	.731
Lower Grand River	1.418	1.774	1.774	1.848	2.022	1.764	1.764	2.122	2.733
Total mgd	5.583	6.204	6.360	7.153	8.082	7.059	7.107	9.972	13.471
Total mg/yr	2037.80	2264.46	2321.40	2610.85	2949.93	2576.54	2594.06	3639.78	4916.92

5.2 COMMERCIAL

While most commercial establishments are connected to a municipal service system, some have been granted permits for obtaining water from private sources by the Ontario Ministry of the Environment. Over 90% of these permits allow ground-water extraction, primarily for the purpose of maintaining viable fish farm enterprises. Table 5.2 indicates the daily and yearly water takings for commercial purposes within the basin. The yearly volume of water was calculated by assuming that commercial establishments consume the maximum amount of water which is allowed daily for use by permit for the number of days allocated for the duration of a year. An inventory of daily commercial water takings by establishment is provided in Appendix D, Tables D1.1 to D1.6.

The use of water by commercial establishments in the future is not expected to increase significantly.

5.3 RECREATIONAL

Recreational uses of water are, for the most part, confined to natural surface water areas or storage ponds. A limited amount of water is extracted for irrigating golf courses, conducting agricultural research and supplying park areas.

The daily water takings for recreational use are approved by the Ontario Ministry of the Environment. The quantity of water allowed for recreational use in each sub-basin sector is shown in Table 5.2. and Appendix E. To estimate the yearly volume of water used for irrigating golf courses, a water use telephone survey was conducted during the fall, 1980. Based on the results of the study, it was estimated that, on the average, golf course operators extract the maximum amount of water allotted daily by the Ministry for approximately 80 days per year. To estimate the yearly volume of water used for other recreational purposes, it was assumed that water is withdrawn for 60 days per year. Table 5.2 outlines daily permitted water takings and the estimated yearly volumes of water withdrawn for recreational uses.

It is expected that water abstraction for recreational use will not increase significantly in the future.

TABLE 5.2

Existing Water Demand for Commercial and Recreational Uses, 1978

Sub-Basin Sector	Commercial (gpd)	Recreational (gpd)	Irrigation (Golf) (gpd)
Lower Grand River	333,000	13 storage ponds	391,680
Whiteman Creek		17 storage ponds	
Nith River		21,600 + 17 storage ponds	121,800
Paris and Middle Grand River	1,569,600	2,353,200 + 28 storage ponds	1,665,700
Conestogo River		3 storage ponds	
Upper Grand River		3 storage ponds	
Total Estimated Withdrawal Rate	1,902,600	2,374,800	2,179,180
Total Estimated Withdrawal Volume/Yr	653,679,000	142,488,000	174,334,400

6. SUMMARY

The total known yearly water withdrawals in the Grand River basin approximate 34 x 10^3 mg (155 x 10^6 m^3) (Table 6.1 and Figure 6.1). Daily consumption ranges from an average of about 100 mgd (455 500 m^3/d) to a maximum of 202 mgd (918 000 m^3/d) during the summer months, assuming maximum withdrawal for irrigation and recreational uses (Table 6.1 and Figure 6.2).

The range in yearly water withdrawals in the Grand River watershed is expected to increase to between 60 x 10^3 mg (273 x 10^6 m^3) and 80 x 10^3 mg (403 x 10^6 m^3) in the year 2001 and 78 x 10^3 mg (355 x 10^6 m^3) and 129 x 10^3 (586 x 10^6 m^3) in the year 2031 (Tables 6.1 and 6.2; and Figure 6.1).

The range in daily water use is expected to increase from an average between 178 and 235 mgd (809 100 and 1 068 200 m^3/d) to a maximum between 369 and 606 mgd (1 677 300 and 2 754 600 m^3/d) in the year 2001. By the year 2031, this daily range is further increased from an average between 233 and 379 mgd (1 059 218 m^3/d and 1 772 934 m^3/d) to a maximum between 424 and 785 mgd (1 927 504 m^3/d and 3 568 610 m^3/d) (Tables 6.2 and 6.3; and Figure 6.2).

The critical areas where water shortages may occur in the future are in the central basin. In the Cities of Kitchener, Waterloo, Cambridge and Guelph, the existing water supply must be supplemented by new water sources by the year 2001 if no conservation measures or new pricing structures are implemented. Two smaller communities, Fergus and Elora, may experience water shortages by the year 2031. The time at which new municipal supplies are required is dependent on population growth and water conservation practices.

TABLE 6.1

Estimates of Existing Water Demand in the Grand River Basin, 1976 - 1979

Sub-Basin Sector	Domestic Rural (gpd) 1979	Livestock (gpd) 1976	Irrigation Crops/Sod (gpd) 1979	Irrigation Golf (gpd) 1979	Municipal (gpd) 1979	Industrial (gpd) 1978-79	Commercial (gpd) 1979	Recreational (gpd) 1979	Total (gpd)
Lower Grand River	1,419,000	1,265,099	32,345,215 + 1 storage pond	391,650	1,542,000	9,764,000	333,000	13 storage ponds	47,059,993
Whiteman Creek	349,000	443,901	53,740,572			109,000		1 storage pond	54,640,373
Nith River	1,035,000	1,991,492	9,993,550	121,900	14,780,000	3,996,000		21,600 + 17 storage ponds	30,939,432
Paris and Middle Grand River	1,764,000	1,644,199	2,245,960	1,665,700	36,069,000	15,446,000	1,612,900	2,353,200 + 29 storage ponds	62,900,759
Conestogo River	696,000	1,762,739			420,000	3,069,000		3 storage ponds	5,946,739
Upper Grand River	322,000	690,712			35,000			3 storage ponds	1,047,712
Total Estimated Withdrawal Rate	5,593,000 2.9%	7,699,030 3.9%	97,325,197 49.1%	2,179,150 1.1%	52,946,000 26.1%	32,382,000 16.0%	1,945,900 0.9%	2,374,900 1.2%	202,334,007
Total Estimated Withdrawal Volumes/yr.	2,037,795,000 6.0%	2,809,790,950 9.3%	486,625,995 1.4%	174,334,400 0.5%	19,299,790,000 56.7%	8,425,179,000 24.9%	69,374,000 1.9%	142,499,000 0.4%	34,034,366,335

TABLE 6.2

Estimates of Future Water Demand in the Grand River Basin, 2001

Sub-Basin Sector	Livestock (mgd)	Irrigation Crops/Sod (mgd)	Irrigation Golf (mgd)	Recreational (mgd)	Municipal (mgd)	Industrial (mgd)	Commercial (mgd)	Domestic Rural (mgd)	Total Water Demand (mgd)
Lower Grand River	0.37 - 1.27	18.83 - 42.45	0.39 - 0.39		22.4 - 31.4	19.0 - 20.8	0.33 - 0.33	1.774 - 2.022	63.094 - 98.502
Whiteman Creek	0.44 - 0.45	47.54 - 76.86	-		-	0.2 - 0.2	-	0.388 - 0.493	48.568 - 78.003
Nith River	1.89 - 2.65	62.22 - 107.93	0.12 - 0.12	.02 - .02	3.28 - 3.88	7.5 - 8.2	-	1.095 - 1.374	76.125 - 124.174
Paris and Middle Grand River	1.64 - 2.93	47.14 - 118.25	1.66 - 1.66	2.35 - 2.35	79.78 - 109.45	24.0 - 32.7	1.61 - 1.61	1.848 - 2.506	160.028 - 271.456
Conestogo River	1.76 - 1.98	6.10 - 11.78			0.55 - 0.69	6.0 - 6.6		0.766 - 1.052	15.176 - 22.102
Upper Grand River	0.69 - 0.75	4.57 - 10.14			0.51 - 0.70	-		0.333 - 0.635	6.103 - 12.225
Total Estimated Withdrawal Rate	6.79 - 10.03	186.40 - 367.41	2.17 - 2.17	2.37 - 2.37	106.52 - 145.96	56.7 - 68.5	1.94 - 1.94	6.204 - 8.082	369.094 - 606.462
Total Estimated Withdrawal Volumes/yr.	2,478.35-3,660.95	931.94-1,837.05	174.33-174.33	142.49-142.49	38,879.80-53,275.40	14,566.0- 17,780.0	669.45-669.45	2,264.46- 2,949.93	60,106.82- 80,489.60

TABLE 6.3

Estimates of Future Water Demand in the Grand River Basin, 2031

Sub-Basin Sector	Livestock (mgd)	Irrigation Crops/Sod (mgd)	Irrigation Golf (mgd)	Recreational (mgd)	Municipal (mgd)	Industrial (mgd)	Commercial (mgd)	Domestic Rural (mgd)	Total Water Demand (mgd)
Lower Grand River	0.37 - 1.27	18.83 - 44.46	0.39 - 0.39	-	30.67 - 51.74	26.5 - 33.9	0.33 - 0.33	1.768 - 2.733	78.854 - 134.823
Whiteman Creek	0.35 - 0.44	47.54 - 76.86	-	-	-	0.3 - 0.3	-	0.431 - 0.731	48.621 - 78.331
Nith River	1.89 - 3.08	62.22 - 122.73	0.12 - 0.12	0.2 - 0.2	3.57 - 5.97	10.4 - 13.4	-	1.274 - 2.137	79.494 - 147.457
Paris and Middle Grand River	1.64 - 3.81	47.14 - 123.35	1.66 - 1.66	2.35 - 2.35	105.44 - 180.38	30.9 - 53.0	1.61 - 1.61	2.225 - 4.541	192.965 - 370.701
Conestogo River	1.76 - 2.57	6.10 - 16.54			0.70 - 1.21	8.3 - 10.6	-	0.933 - 1.958	17.793 - 32.878
Upper Grand River	0.69 - 0.75	4.51 - 16.91			0.76 - 1.54	-	-	0.432 - 1.371	6.392 - 20.571
Total Estimated Withdrawal Rate	6.70 - 11.92	186.34 - 400.85	2.17 - 2.17	2.37 - 2.37	141.14 - 240.84	76.4 - 111.2	1.94 - 1.94	7.059 - 13.47	424.119 - 784.761
Total Estimated Withdrawal Volumes/yr.	2,478.35-4,350.80	931.94-2,004.19	174.33-174.33	142.49-142.49	51,516.10-87,906.60	19,613.0-28,872.0	669.45-669.45	2,576.50- 4,916.915	78,102.16- 129,167.76

FIGURE 6.1 SUMMARY OF EXISTING AND ESTIMATED FUTURE YEARLY WATER DEMAND BY VOLUME IN THE GRAND RIVER BASIN

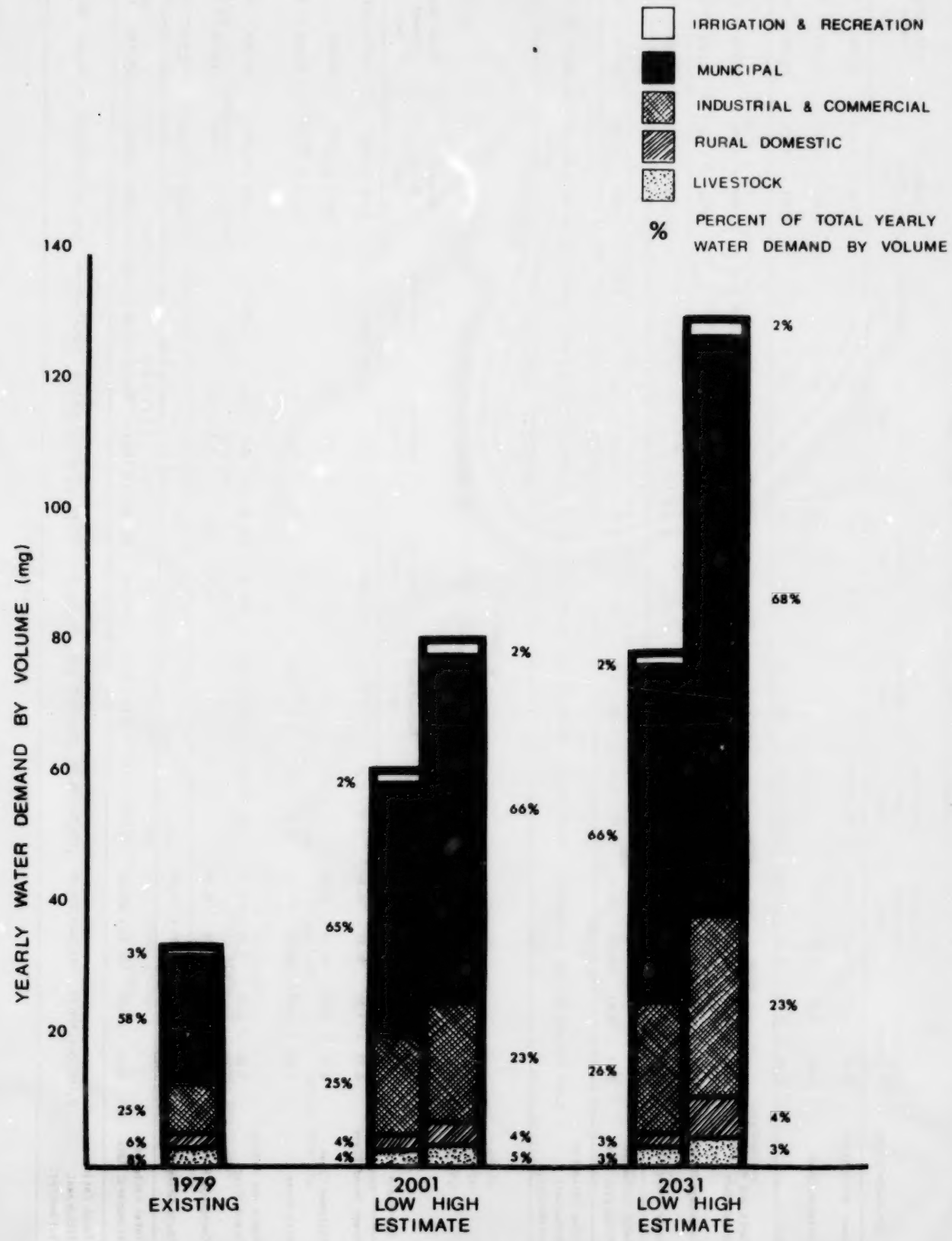
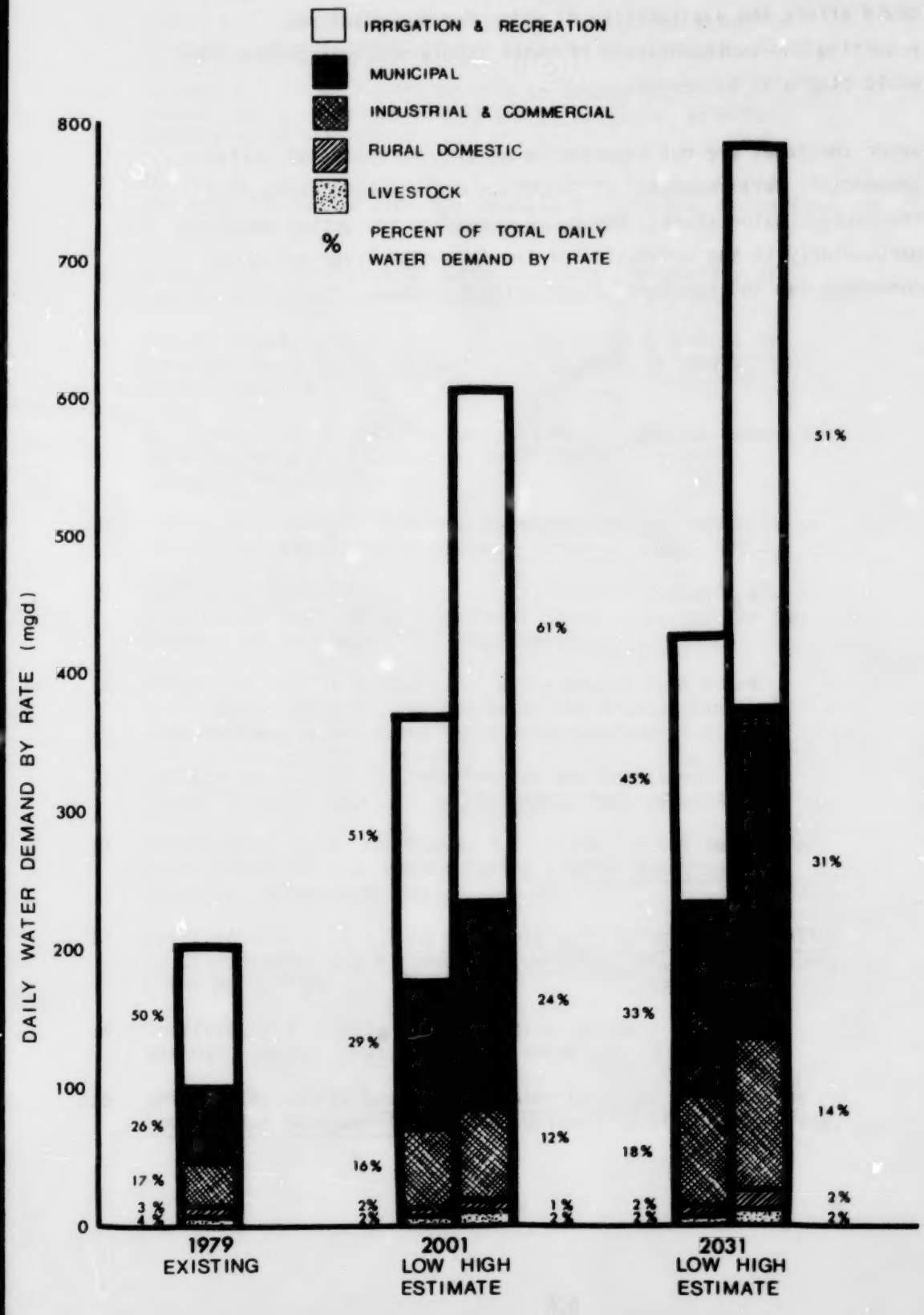


FIGURE 6.2 SUMMARY OF EXISTING AND ESTIMATED FUTURE DAILY WATER DEMAND BY RATE IN THE GRAND RIVER BASIN



Abstraction of water in the central basin to meet projected needs could affect the availability of water for municipal use requiring the implementation of water supply projects before they would otherwise be needed.

Water shortages are not expected in meeting recreational, private commercial, rural domestic or livestock water demand throughout the basin. Water storage may be required for irrigating crops, particularly in the sub-basins of the Conestogo River below the Conestogo dam and the Speed River below Guelph.

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APPENDIX A

MUNICIPAL WATER TAKINGS

APPENDIX A

MUNICIPAL WATER-TAKINGS

Appendix A consists of a set of Grand River sub-basin maps which indicates the location of municipal water-takings updated to September 1982. These maps are available for viewing and study at selected basin municipality libraries, the Ministry of the Environment regional offices in London and Hamilton, and the Grand River Conservation Authority in Cambridge.

These maps differentiate various sources of permitted water takings (ie. stream takings, wells, or dugout ponds). The information presented is based on detailed data provided by the Ministry of the Environment. These data, compiled relevant to the sub-basins outlined in Figure 2.2, are summarized in Table 6.1. The locations of permitted municipal water-takings are illustrated in Figures A1.B - A1.M using base maps provided by the Ministry and consequently, sub-basin titles and boundaries vary slightly from those used in the Basin Study. Locations of permitted water-takings are indicated by a permit number which relates to the number of permits located within a particular sub-basin, not the Ministry's file permit number. Detailed information relating to permitted municipal water-takings is available at the Ministry's regional offices.

APPENDIX B

URBAN WATER CONSUMPTION DATA FOR THE CITIES OF KITCHENER, WATERLOO, CAMBRIDGE, GUELPH AND BRANTFORD, 1978

APPENDIX B

URBAN WATER CONSUMPTION DATA, 1978

B1.1 Introduction

This appendix presents a detailed description of municipal water consumption for the five large urban centers within the Grand River basin. The analysis is based on 1978 consumption data, the results of which are outlined in Table B1.1. Section B1.2 provides a general description of methodology and data sources while section B1.3 gives a detailed account of the calculations and assumptions made for each centre.

Although it is preferable to use several years of data to estimate mean consumption rates, the level of detail necessary for the analysis in addition to time constraints limited data collection. However, time series data were investigated for the City of Brantford. The mean per capita consumption net of losses was 114 gpd with a standard deviation of 4 gpd. The 1978 observation deviated from the mean by one standard deviation to give a 3.5% error. In light of the approximations made elsewhere in this analysis, this error seemed acceptable.

Consumption statistics for each community were not derived from uniform sets of raw data. Moreover, some tenuous assumptions were made in order to undertake the analysis. These failings suggest that further work undertaken with these statistics must be interpreted with caution.

TABLE B1.1

Urban Water Consumption Characteristics

City	Waterloo	Kitchener	Guelph	Brantford	Cambridge	Average
Service Connections						
Residential	11,898	28,826	14,745	19,096	18,218	
Apartment Bldgs.	256	819	415	301	289	
Institutions	70	170	150	140	150	
Commercial	915	1,516	1,045	1,291	839	
Industrial	196	164	193	222	207	
Total	13,335	31,495	16,548	21,050	19,703	
Annual Consumption Breakdown (%)						
Residential	31	26	25	26	27	26
Apartment	10	12	9	6	7	9
Institutional	15	6	13	4	5	10
Commercial	12	10	5	4	15	9
Industrial	20	36	25	40	26	30
Unaccounted	12	10	23	20	20	19
Total	100	100	100	100	100	
1978 Pumpage (1,000's gal)	1,865,855	5,037,516	3,423,466	3,627,851	3,054,620	
Population Served	51,473	133,815	71,349	69,091	72,950	
Total gpd/Capita	99	103	131	143	115	119
Average Summer Day ÷ Average Winter Day	1.12	1.17	1.15	1.28	1.12	1.17
Maximum Day ÷ Average Day	1.65	1.55	1.70	1.61	1.54	1.62
Residential Consumption (gpd/meter)						
Average annual	133	126	159	135	124	133
Average winter	122	106	118	81	112	105
Average summer	166	176	189	183	155	171
Maximum day	381	362	479	419	321	392
Total Serviced Dwelling Units	16,993	43,806	23,048	25,119	23,988	
Persons/Dwelling Unit	3.03	3.05	3.10	2.75	3.04	2.99

B1.2 General Notes and Assumptions

(a) Base Year

1978 consumption data and population figures are used throughout this analysis. Information concerning the number of connections, the percentage breakdown of consumption, etc. was obtained from the most recent available year and, where necessary, pro-rated to 1978.

(b) Institutions

The number of institutional connections was estimated by counting school, church and government addresses listed in 1978 telephone directories.

(c) Consumption by Apartment Dwellers

A sample of data on apartment consumption was available from Kitchener for two twelve month periods in 1977 and 1978-79. This data was used to estimate an average per unit daily consumption rate of 103 gallons. It was assumed that this rate is constant throughout the year. This assumption is supported by t-tests comparing summer month consumption to winter month consumption; using a one-tail test, no significant difference was found at an 80% level of confidence.

A summary of the analysis of this data is given in Table B1.2.

(d) Number of Apartment Buildings

Where no information was available on the total number of apartment buildings in a community, the number was estimated by dividing the total number of apartment units by the average number of units per building. Two data sources were used to estimate the average number of units per building. The first was a partial sample of apartment buildings in Waterloo. The second pertained to Kitchener, where data outlining the total number of apartment building service connections were supplied by the city. The number of units was estimated by adding the 1976 census count of apartment

TABLE B1.2

Tests on Monthly Apartment Consumption in the City of Kitchener

Period	Flow (gpd/Apartment) Mean	St. Dev.	Sample Size (Bldgs.)	t-Tests/F-Tests: Annual	Winter	Summer
Annual (1978-79)	100.1	23.0	9	-	-	-
Winter (1978-79)	100.00	21.9	9	-.0036/1.10	-	-
Summer (1978-79)	100.2	27.6	9	.0087/1.44	.012/1.59	-
Annual (1977)	102.9	37.6	13	-	-	-
Winter (1977)	101.04	30.12	13	-.16/1.11	-	-
Summer (1977)	108.43	37.6	13	.42/1.40	.57/1.56	-

units to the number of apartment unit completions for the years 1976 and 1977. Unit completion data was obtained from the Canada Mortgage and Housing Corporation (CMHC).

The Waterloo data indicate a value of 25 units per building while the Kitchener data indicate a value of 19 units per building. A weighted average value of 20 units per building was used for the analysis.

(e) Seasonal Variability of Consumption

It was assumed that commercial, industrial, apartment and institutional consumption remain constant throughout any given year. The loss, estimated as a percentage of total pumpage, was assumed to vary proportionately with pumpage. The remaining variability was assumed to be caused by domestic consumption. Thus, domestic consumption and losses were assumed to be the cause of high summer pumpage.

The assumption that non-residential consumption does not vary significantly with the seasons is supported by non-residential consumption data from Guelph. Four years of monthly data from 1974 to 1977 were available. Summary statistics for this data are given in Table B1.3. The analysis of seasonal consumption for apartments, given in Table B1.2, provides further support for this assumption.

Table B1.3

Tests on Monthly Industrial Consumption in the City of Guelph, 1974 to 1977

	Flow (1,000's gal/mo)		Sample Size	t-Tests/F-Tests		
Period	Mean	St. Dev.	(Months)	Annual	Winter	Summer
Annual	147,339	15,987	48	-	-	-
Winter	149,707	15,191	36	.68/1.05	-	-
Summer	140,234	16,866	12	-1.34/1.05	-1.78/1.11	-

One tail t-tests on the various means provided no evidence of significant difference at an 80% level. The summer mean was below the winter mean, contrary to expectations.

(f) Residential Consumption

Residential consumption was considered to be water consumed by individually metered dwelling units. The following formulae are used to estimate domestic consumption per dwelling unit.

$$DA = (TA\ (1 - L) - I)/N$$
$$DS = (TS\ (1 - L) - I)/N \text{ (Summer)}$$
$$DW = (TW\ (1 - L) - I)/N \text{ (Winter)}$$
$$DM = (MAX\ (1 - L) - I)/N \text{ (Maximum Day)}$$

where:

TA = total average daily consumption over the year
TS = total average daily consumption over June, July, August
TW = total average daily consumption over the remainder of year
MAX = total maximum day consumption
L = percentage loss
I = average daily non-residential consumption
N = number of domestic connections
DA = domestic average daily consumption over the year
DS = domestic average daily consumption over June, July, August (summer consumption)
DW = domestic average daily consumption over the remainder of year (winter consumption)

(g) Summer Sprinkling Demand

The amount of water used for summer lawn sprinkling was estimated based on observed data for each major urban centre. For the summer months, the sum of the water consumed for industrial, residential, apartment, commercial, and institutional purposes and the water lost through system leakages was

subtracted from the total water consumption figure for each centre. The residual was assumed to be used for summer lawn sprinkling. The results obtained by this method approximated the results obtained by Howe and Linaweaver (1967).

(h) Data References

1. Business Establishments - 1971 Census
   Manufacturing Industries of Canada: Geographical Distribution. Statistics Canada, catalogue 31-209.
2. Retail Trade: Countries or Census Divisions, Criteria and Towns. Statistics Canada, catalogue 97-7803.
3. Wholesale Trade: Countries or Census Divisions, Metropolitan Areas, Cities, Towns. Statistics Canada, catalogue 97-723.
4. Service Trades: Countries or Census Divisions, Cities and Towns. Statistics Canada, catalogue 97-743.
5. Apartments and Dwelling Units - 1976 Census
   Population: Geographic Distributions. Statistics Canada, catalogue 92-810.
6. Housing Completions - 1976, 1977
   personal communication - Canada Mortgage and Housing Corporation (CMHC).
7. Consumption data, service connection - 1978
   personal communication - City water directors, planners and Regional Municipality of Waterloo water managers.
8. M.O.E. files (annual pumping reports and reserve capacity evaluations for Municipalities).

B1.3 Forecasting Industrial Water Consumption: A Case Study in "1.6" Analytics

The forecasting of industrial water consumption for those industries linked to a municipal water supply was carried out based on observed data. The following methodology was used to calculate future industrial water consumption in each major centre:

1. Data were collected regarding the industrial water consumption per capita for each major centre (Appendix B1.4)

2. Data were collected describing the amount of water consumed per industrial employee per year for various industrial types (Table B1.4)

3. Forecasts were carried out for the base case and the water conservation case according to the following mathematical equations:

i) Base Case forecasts = W x POP
where:
W = observed per capita industrial water consumption
POP = forecast population

ii) Water Conservation forecasts = $[POP_{78} \times W] + [\triangle POP \times W \times F]$
where:
POP_{78} = existing population, 1978
W = observed per capita industrial water consumption
$\triangle$ POP = forecast population increments
F = adjusting factor

NOTE: The water conservation forecasts assume that new per capita industrial consumption falls by a factor, "F", while existing industrial activity remains unchanged in its consumption behaviour.

F = [E_i (percentage employment by industry') x (industrial consumption rate per employee)] ÷ [E_i (percentage employment by industry) x (industrial consumption rate)]
= (E_i (P' x I)) ÷ (E_i (P x I)), i = 1...19

where:

P = percentage of total industrial employees in each of 19 industries

$E_i P = 1$, $i = 1...19$

$P' = (P \times B) \div E_i P \times B$, $E_i P' = 1$, $i = 1...19$

B = boolean vector where $b_i = 1$ if industry i consumes little water

where $b_i = 0$ if industry i consumes much water (Table B1.4)

TABLE B1.4

Industry Consumption Rates (Great Lakes Region)[1]

Industry	Water Consumption/yr Employee (10^6 U.S. gal) I	Boolean Vector B
Food Products	0.8031	1
Tobacco	-	1
Textiles	0.3389	1
Clothing	0.00876[2]	1
Lumber	1.1388	1
Furniture	0.136	1
Paper Products	5.032	0
Publishing	0.00657[2]	1
Chemicals	4.9086	0
Petroleum	12.8167	0
Rubber and Plastics	0.5371	1
Leather	0.4655	1
Stone and Clay Products	1.5482	1
Primary Metals	8.2602	0
Metal Fabricating	0.2168	1
Machinery	0.1366	1
Electrical Products	0.1226	1
Transportation	0.2184	1
Miscellaneous	0.2045	1

[1]Source: Personal communication, Donald Tate, Environment Canada, 1980.

[2]Source: Forecasting Municipal Water Requirements, Vol. 1, The Main II System, September 1969.

B1.4 Detailed Working Notes

(A) ANALYSIS OF BRANTFORD WATER CONSUMPTION (1978)

(i) RESULTS

a) Service Connections

Residential	19,096
Apartment	301
Institutional	140
Commercial	1,291
Industrial	222
Total	21,050

b) Annual Consumption Breakdown

	Percentage	1,000's gal.	1,000's GPD
Residential	26	943,241	2,584
Apartment	6	217,671	596
Institutional	4	145,114	398
Commercial	4	145,175	398
Industrial	40	1,451,140	3,976
Unaccounted	20	725,510	1,988
	100	3,627,851	9,940

Population served = 69,091

gpd/capita = 143

c) Total Seasonal Consumption

	1,000's gpd
Average winter	8,645
Average summer	11,068
Maximum day	16,718

d) **Unaccounted Seasonal Consumption**

	1,000's gpd
Average winter	1,729
Average summer	2,214
Maximum day	3,344

e) **Residential Seasonal Consumption**

	gpd/Meter
Average annual	135
Average winter	81
Average summer	183
Maximum day	419

(ii) **ASSUMPTIONS AND NOTES**

a) **Service Connections**

			Source of Data
(1)	1978 total service connections (net of township connections)	= 21,050	City of Brantford
(2)	Number of institutions	= 140	telephone directory
	1976 apartment units	= 4,775	1976 Census
	1976-1977 apartment completions	= 1,248	CMHC
	1978 apartment units	= 6,023	
(3)	1978 apartment buildings = 6,0[illegible]/20	= 301	by assumption
	1976 dwelling units net of apartments	= 17,760	1976 Census
	1976-1977 dwelling unit completions	= 1,336	CMHC
(4)	1978 residential connections	= 19,096	

(5) 1978 commercial and industrial connections

(1) - (2) - (3) - (4) = 1,513

1971 commercial establishments	= 901	1971 Census
1971 industrial establishments	= 155	
Total	= 1,056	

assume constant proportions, therefore:

1978 Commercial establishments = (901/1,056) x (5) = 1,219

1978 Industrial establishments = (155/1,056) x (5) = 222

b) **Consumption Breakdown**

1978 total pumpage (net of township sales)	= 3,627,851,000 gal.	City of Brantford
1978 total metered sales	= 2,888,496,000 gal.	
1978 unaccounted	= 739,356,000 gal.	
	= 20%	
1978 total apartment consumption = 6,023 units x 103 gpd x 365 days	= 226,435,000 gal.	By assumption
	= 6%	
1978 consumption by 9 largest industries	= 1,142,445,000 gal.	City of
	= 31%	Brantford
1978 consumption by General Hospital	= 74,760,000 gal.	City of
	= 2%	Brantford
1978 consumption through 5/8" and 3/4" meters*	= 1,108,756,300 gal.	City of
	= 31%	Brantford
1978 consumption through meter larger than 3/4"	= 1,779,754,500 gal.	City of
	= 49%	Brantford

Proposed 1978 Breakdown

By assumption	
Residential	26%
Apartment	6%
Institutions	4%
Commercial	4%
Industrial	40%
Unaccounted	20%
	100%

c) **Comparison of Consumption Through Time**

Year	Daily	% Unaccounted Consumption	Net Consumption Per Capita
1971	8,523,287 gal.	20	111 gal.
1972	8,600,000	20.6	106
1973	8,420,466	13.3	112
1974	8,664,664	10.6	119
1975	8,971,315	15.6	116
1976	9,527,369	20.8	113
1977	10,397,411	21.6	118
1978	10,221,919	20.3	118
		mean	114
		S.D.	4

d) **Large Consumers in Brantford**

	Total Consumption (1,000's gal.)	Average Day (1,000's gal.)
Harding Carpet	182,227	499
Massey Verity	144,949	397
Diamond National	77,032	211
Sunoco	62,811	172

York Farris	61,993	170
Massey Heary St.	58,206	159
Massey Combine	52,393	144
Hessmann	39,048	107
Johnson Wax	37,964	104
B. General Hospital	37,038	101
White Farm Equipment	23,491	64
Atlas Chemical	22,364	61

Period of consumption 1-79 to 12-79

(B) ANALYSIS OF GUELPH WATER CONSUMPTION (1978)

(i) RESULTS

a) **Service Connections**

Residential	14,745
Apartment	415
Institutional	150
Commercial	1,045
Industrial	193
Total	16,548

b) **Annual Consumption Breakdown**

	Percentage	1,000's Gal.	1,000's gpd
Residential	25	855,867	2,345
Apartment	9	308,112	844
Institutional	13	445,051	1,219
Commercial	5	171,173	469
Industrial	25	855,867	2,345
Unaccounted	23	781,835	2,142
Total	100	3,417,905	9,364

Population served = 71,349
gpd/capita = 131

c) **Total Seasonal Consumption**

	1,000's gpd
Average Winter	9,037
Average Summer	10,396
Maximum Day	15,940

d) **Unaccounted Seasonal Consumption**

	1,000's gpd
Average Winter	2,079
Average Summer	2,391
Maximum Day	3,666

e) **Residential Seasonal Consumption**

	gpd/Meter
Average Annual	159
Average Winter	118
Average Summer	189
Maximum Day	479

(ii) **ASSUMPTIONS AND NOTES**

a) **Service Connections:**		SOURCE OF DATA
(1) 1978 Total Service Connections	= 16,548	City of Guelph
(2) 1978 Apartment Units	= 8,303	City of Guelph
(3) 1978 Apartment Buildings = 8,303/20	= 415	
1976 Total Dwelling Units	= 22,105	1976 Census
1976-1977 Completions	= 1,743	CMHC

(4) 1978 Dwelling Units = 23,848

(5) 1978 Non-Serviced Homes = 800 By assumption
(located in recently annexed areas)

(6) 1978 Residential
Connections = (4) - (2) - (5) = 14,745

(7) 1978 Institution Connections = 150 Telephone directory

(8) 1978 Commercial and Industrial
Connections = (1) - (3) - (6) - (7) = 1,238

1971 Commercial establishments	=	740	1971 Census
1971 Industrial Establishments	=	137	
Total	=	877	

Assume constant proportions, therefore:

1978 Commercial Connections = (740/877) x 1,238
= 1,045

1978 Industrial Connections = (137/877) x 1,238
= 193

b) **Consumption Breakdown**

1978 Total Pumpage	= 3,423,466,000 gal.	City of Guelph
1978 Total Sales	= 2,641,631,000 gal.	
1978 Unaccounted	= 781,835,000 gal.	
	= 23%	

1978 Apartment Consumption =
8,303 units x 103 gpd x 365 days = 312,151,000 gal. By assumption
= 9%

1978 Consumption by 24 Largest Firms	= 629,200,000 gal. = 18%	City of Guelph*
1978-79 Consumption by 3 Largest Institutions	= 311,974,000 gal. = 9%	City of Guelph**
1977 Consumption Sold at Block 1 Rates	= 1,201,026,120 gal. = 35% of 1977 pumpage	City of Guelph***

Proposed Breakdown for 1978: By assumption

Domestic	25%
Commercial	5%
Industrial	25%
Institutional	13%
Apartment	9%
Loss	23%

* 12 month period commencing 7/78

** 12 month period commencing 12/78

*** Primarily residential, commercial, small apartment buildings

c) Large Consumers in Guelph

	Total Consumption (1,000's gal.)	Average Day (1,000's gal.)
Pirelli	324,582	889
Fiberglas	75,660	207
Dayton Walther	69,320	190
Hart Chemical	38,943	107
Court Galvanizing	26,455	72
Omark	21,903	60
C.G.E.	20,789	57
W. C. Wood	18,206	50
International Malleable	17,469	48
Imperial Tobacco	16,693	46
Period of Consumption 7-78 to 6-79		
University of Guelph	269,227	738
St. Josephs	22,204	61
General Hospital	20,543	56
Period of Consumption 12-78 to 11-79		

(C) ANALYSIS OF CAMBRIDGE WATER CONSUMPTION (1978)

(i) RESULTS

a) Service Connections

Residential	18,218
Apartment	289
Institutional	150

Commercial	839
Industrial	207
Total	19,703

b) **Annual Consumption Breakdown**

	Percentage	1,000's gal.	1,000's GPD
Residential	27	824,748	2,260
Apartment	7	213,823	586
Institutional	5	152,731	418
Commercial	15	458,193	1,255
Industrial	26	794,201	2,176
Unaccounted	20	610,924	1,674
Total	100	3,054,620	8,369

Population Served = 72,950
Total gpd/capita = 115

c) **Total Seasonal Consumption**

	1,000's gpd
Average Winter	8,097
Average Summer	9,078
Maximum Day	12,860

d) **Unaccounted Seasonal Consumption**

	1,000's gpd
Average Summer	1,816
Average Winter	1,619
Maximum Day	2,572

e) **Residential Seasonal Consumption**

	gpd/Meter
Average Annual	124
Average Winter	112
Average Summer	155
Maximum Day	321

(ii) **ASSUMPTIONS AND NOTES:**

a) **Service Connections:**		SOURCE OF DATA
(1) 1978 Total Service Connections	= 19,703	
(2) 1978 Total Residential Connections	= 18,218	City of Cambridge
(3) 1978 Total Non-Residential Connections	= 1,485	
1976 Apartment Units	= 5,335	1976 Census
1976-1977 Additions	= 435	CMHC
1978 Apartment Units	= 5,770	
(4) 1978 Apartment Connections = 5,770/20	= 289	By assumption
(5) 1978 Institutional Connections	= 150	Telephone directory
(6) 1978 Commercial and Industrial Connections = (3) - (4) - (5)	= 1,046	
1971 Commercial Establishments	= 759	1971
1971 Industrial Establishments	= 187	Census
Total	= 946	

Assume Constant Proportions, therefore

1978 Industrial Connections = (187/946) x 1,046
= 207

1978 Commercial Connections = (759/946) x 1,046
= 839

b) **Consumption Breakdown**

1977 Total Pumpage	= 3,047,157,000 gal.	City
1977 Total Sales	= 2,290,479,000 gal.	of
1977 Unaccounted	= 756,678,000 gal.	Cambridge
	= 25%	

1977 Total Apartment Consumption =
5,419 units x 103 gpd x 365 days = 203,727,000 gal. By assumption
= 7%

1977 Consumption by 9 Largest Industrial Consumers	= 498,955,000	City of
	= 16%	Cambridge
1977 Consumption by Largest Institutional Consumer	= 35,770,000	City of
	= 1%	Cambridge

1975 Consumption Breakdown — Canada Water Inventory

Residential	27%
Non-Residential	53%
Unaccounted	20%

1978 Proposed Breakdown — By assumption

Residential	27%
Apartment	7%

Institutional	5%
Industrial	26%
Commercial	15%
Loss	20%

c) **Large Consumers in Cambridge**

	Total Consumption (1,000's gal.)	Average Day (1,000's gal.)
Canadian General Tower	93,805	257
Hostess Foods	83,950	230
Galtex	67,160	184
Babcock - Wilcox	50,005	137
Dobbie Industries	50,005	137
Centex	45,260	124
Galt Malleable Iron	44,165	121
Franklin Manufacturing	39,785	109
South-Waterloo Memorial Hospital	35,770	98
Long Manufacturing	24,820	68

Period of Consumption 1-77 to 12-77

(D) **ANALYSIS OF KITCHENER WATER CONSUMPTION (1978)**

(ii) **RESULTS**

a) **Service Connections**

Residential	28,826
Apartment	819
Institutional	170
Commercial	1,516
Industry	164
Total	31,495

b) **Annual Consumption Breakdown**

	Percentage	1,000's gal.	1,000's gpd
Residential	26	1,325,048	3,630
Apartment	12	597,911	1,638
Institutional	6	255,144	699
Commercial	10	535,475	1,467
Industry	36	1,840,954	5,043
Unaccounted	10	482,984	1,323
Total	100	5,037,516	13,801

Popultion served = 133,815
gpd/capita = 103

c) **Total Seasonal Consumption**

	1,000's gpd
Average Winter	13,235
Average Summer	15,482
Maximum Day	21,422

d) **Unaccounted Seasonal Consumption**

	1,000's gpd
Average Winter	1,324
Average Summer	1,548
Maximum Day	2,142

e) **Residential Seasonal Consumption**

	gpd/Meter
Average Annual	126
Average Winter	106
Average Summer	176
Maximum Day	362

(ii) **ASSUMPTIONS AND NOTES:**

a) **Service Connections 1978**

		SOURCE OF DATA
Residential	28,826	
Commercial	1,686	City
Apartments	819	of
Industry	164	Kitchener
Total	31,495	
Institutional (component of commercial)	170	Telephone Directory

Apartment Units

1976 apartment units	= 14,980	1976 Census
1976-1977 completions	= 924	CMHC
1978 apartment units	= 15,904	

b) **Consumption Breakdown**

(1)	1978 total pumpage	= 5,037,516,000 gal.	City of
(2)	1978 total sales	= 4,554,532,000 gal.	Kitchener
(3)	1978 unaccounted = (1) - (2)	= 482,984,000 gal.	
		= 10%	

(4)	1978 apartment consumption 14,980 units x 103 gpd x 365 days	= 597,911,000 gal. = 12%	By assumption
(5)	Value of 1978 residential water sales	= $1,060,038	City of Kitchener
	At 85.1¢/1,000 gal. for 0-3,115 gal./month, 70.6¢/1,000 gal. for 3,115-105,910 gal./month and 64.2¢/1,000 gal. for 105,911-186,900 gal./month assume an average price of 80¢/1,000 gal.		
(6)	1978 residential consumption	= ((5) - .80) x 1,000 = 1,325,048,000 gal. = 26%	By assumption
(7)	Value of 1978 commercial and city government sales at prices given above assume an average price of 70¢/1,000 gal.	= $553,433	City of Kitchener
(8)	1978 commercial and government consumption = ((7) - .70) x 1,000 gal.	= 790,619,000 gal. = 16%	By assumption
	1978 consumption by two hospitals	= 127,572,000 gal. = 3%	City of Kitchener
(9)	1978 institutional consumption	= 255,144,000 gal. = 6%	By assumption

(10) 1978 commercial consumption = (8) - (9)
= 535,475,000 gal. By assumption
= 10%

1978 consumption by 8
largest firms = 1,218,751,000 gal. City of
= 24% Kitchener

(11) 1978 industrial consumption = (1)-(3)-(4)-(6)-(8)
= 1,840,954,000 gal.
= 36%

c) **Large Consumers in Cambridge**

	Total Consumption (1,000's gal.)	Average Day (1,000's gal.)
J. M. Schneider	444,122	1,217
Burns Meats	135,281	371
B. F. Goodrich (521 King W.)	99,897	274
K. W. Hospital	96,625	265
Uniroyal (51 Breithaupt)	87,221	239
B. F. Goodrich (Goodrich Dr.)	80,884	222
Uniroyal (149 Strange)	79,754	219
Robson-Lang Leathers	62,662	172
Lear Siegler Ind.	61,103	167
Uniroyal (84 Margaret)	59,793	164
Budd Automotive Co.	34,377	94
St. Mary's Hospital	30,937	85
Lear Siegler (Ottawa St.)	23,901	65
Kaufman Footwear	11,501	32
Electrohome	11,481	31

Period of consumption 10-78 to 9-79

(E) ANALYSIS OF WATERLOO WATER CONSUMPTION (1978)

(i) RESULTS

a) Service Connections

Residential	11,898
Apartment	256
Institutional	70
Commercial	915
Industrial	196
Total	13,335

b) Annual Consumption Breakdown

	Percentage		1,000's gal.	1,000's gpd	
Residential	31		578,415	1,585	
Apartment	10		186,586	511	
Institutional	15	57	279,878	767	2,913
Commercial	12		223,903	613	
Industrial	20		373,171	1,022	
Unaccounted	12		223,903	613	
Total	100		1,865,865	5,111	

Population served = 51,473

gpd/capita = 99

c) **Total Seasonal Consumption**

	1,000's gpd
Average Winter	4,961
Average Summer	5,559
Maximum Day	8,457

d) **Unaccounted Seasonal Consumption**

	1,000's gpd
Average Winter	594
Average Summer	672
Maximum Day	1,015

e) **Residential Consumption**

	gpd/Meter
Average Annual	133
Average Winter	122
Average Summer	166
Maximum Day	381

(ii) **ASSUMPTIONS AND NOTES:**

a) **Service Connections**

		SOURCE OF DATA
(1) 1978 total service connections	= 13,335	City of Waterloo
1976 dwelling units net of apartments	= 10,315	1976 Census
1976-1977 dwelling unit completions	= 1,583	CMHC
(2) 1978 residential connections	= 11,898	

	1976 apartment units	= 5,095	1976 Census
	1976-1977 apartment completions	= 21	CMHC
(3)	1978 apartment units	= 5,116	
(4)	1978 apartment building connections 5,116/20	= 256	By assumption
(5)	1978 institution connections	= 70	Telephone directory
(6)	1978 industrial and commercial connections (1)-(2)-(4)-(5)	= 1,111	
	1971 industrial establishments	= 83	1971 Census
	1971 commercial establishments	= 388	
	Total	= 471	

assume constant proportions therefore

(7) 1978 industrial connections = (83/471)1,111
= 196

(8) 1978 commercial connections = (388/471)1,111
= 915

b) Consumption Breakdown

1978 total pumpage	= 1,865,855,000 gal.	
1978 residential water sales revenue	= $303,281.29	City of Waterloo
1978 non-residential water sales revenue	= $563,128.62	

Water price = $.53/1,000 gal.

Residential consumption	= 30,328,129/53	
	= 572,228,849 gal.	
	= 31%	
Non-residential consumption	= 56,312,862/53	
	= 1,062,506,830 gal.	
	= 57%	

These categories include consumption by apartments: By
5,116 units x 103 gpd/unit x 365 days = 19,233,600 assumption
= 10%

1978 consumption by universities	= 178,850,000 gal.	City of
	= 9%	Waterloo
1978 consumption by 8 largest firms	= 228,855,000 gal.	City of
	= 12%	Waterloo

1975 consumption breakdown:		Canada
Domestic	30%	Water
Commercial	10%	Inventory
Industrial	35%	
Institutional	15%	
Loss	10%	

Proposed breakdown for 1978:	
Domestic	31%
Commercial	12%
Industrial	20%
Apartment	10%
Institutional	15%
Loss	12%

c) **Large Consumers in Waterloo**

	Total Consumption (1,000's gal.)	Average Day (1,000's gal.)
University of Waterloo	164,250	450
Labatt's Brewery	129,210	354
Leigh Industries	41,975	115
Kraus Carpets	24,090	66
Richmond Square	16,425	45
Wilfrid Laurier University	14,600	40
Bauer Industries	6,205	17
Sunar Industries	4,745	13
Mutual Life	4,745	13
Marsland Centre	1,460	4

Period of consumption 1-78 to 12-78

APPENDIX C

ESTIMATION OF DWELLING UNIT TYPES FOR WATER DEMAND PROJECTIONS

APPENDIX C

ESTIMATION OF DWELLING UNIT TYPES FOR WATER DEMAND PROJECTIONS

C1.1 Introduction

This appendix presents a methodology for prediction of the mix of dwelling types in urban areas based on forecast population levels. The methodology was developed for use in the study of urban water demand within the Grand River basin. Regression analysis was used to identify a functional relationship between the mix of dwelling types and populations.

C1.2 Functional Relationship

Since residential consumption of water varies with the type of residential dwelling unit, it is necessary to distinguish between apartment units and detached, semi-detached and attached units. Consumption patterns of apartment dwellers may differ from other groups for two reasons: apartments are not usually metered individually so that apartment dwellers do not pay directly for water consumed; and since apartment dwellers do not tend any lawn area, the seasonal variation of their consumption is not as great. In a water demand study, it is also useful to differentiate between the three types of non-apartment dwelling units. Detached, semi-detached and attached dwelling units generally are built on varying lot sizes, with detached homes on the largest lots. Lot size will determine lawn area and therefore the likely contribution of each dwelling unit to summer sprinkling water demand.

The dependant variables in this study are the proportion of dwelling units in the community that are apartment units (A), the proportion of non-apartment units that are attached units (R), and the proportion of non-apartment units that are semi-detached (S). These variables measure housing density, a characteristic or dimension of housing that is determined in part in the market for housing. The supply side of this market depends on land costs, construction costs, and other costs. Construction costs were assumed to be similar across southern Ontario and since the data base is cross-sectional, it was legitimate to ignore these costs. Land prices

reflect a community's geographic location, its economic base, its size, etc. Population size (P) was used as a proxy to measure these factors. Two variables were used to measure the impact of demand on housing density. These are the income level (Y) of the population, and the average family size (F) in the community. General expressions for the reduced form equation of this model of the market are:

$$A = f(P,F,Y),\ R = g(P,F,Y),\ S = d(P,F,Y)$$

where f, g and d designate unspecified functional forms.

C1.3 Data

Forty-five communities from the southern half of Ontario were included in the sample. Population and dwelling type data were obtained for 1976 from the 1976 Census report "Population: Geographic Distribution" (catalogue number 92-810). A measure of average income per household was based on the total income reported on taxable income tax returns filed in each community in 1977. This data was obtained from the Revenue Canada publication, "Taxation Statistics - 1977". This measure of income was divided by the total number of dwelling units reported in the census for each community in order to get a measure of income per dwelling unit. Descriptive statistics for these variables are given in Table C1.1.

TABLE C1.1
Sample Data

Variable	Description	Mean	Standard Deviation	Simple Correlations P	F	Y
A	Apartment Units/ Total D.U.*	.216	.096	.532	-.482	.475
R	Attached Units/ Total D.U.-Apts.	.141	.081	.387	.192	.455
S	Semi-Detached Units/ Total D.U.-Apts.	.061	.032	-.059	-.628	-.122
P	Population (10^4 persons)	10.781	31.877	1.0	-.113	.150
F	Family Size (Persons/D.U.)	3.096	.202	--	1.0	.051
Y	Household Income ($\$10^5$/D.U.)	.205	.041	--	--	1.0

*D.U. = Dwelling Unit

C1.4 Results

Linear and non-linear relationships were tested. Five of these tests are reported below:

(1) $A = .640 + .022\ (p^{.5}) - .213\ F + .890\ Y$
(6.14) (-5.49) (4.53)
$r^2 = 73.26,\ F = 37.43,\ n = 45$

(2) $A = .670 + .001\ P - .219\ F + 1.035\ Y$
(4.41) (-4.96) (4.71)
$r^2 = 65.2,\ F = 25.6,\ n = 45$

(3) $\ln(A) = 3.355 + .181\ \ln(P) - 3.551\ \ln(F) + .758\ \ln(Y)$
(4.80) (-5.21) (3.75)
$r^2 = 66.34,\ F = 26.94,\ n = 45$

(4) $\ln(S) = 4.865 - 7.715\ \ln(F) = .524\ \ln(Y)$
(-6.10) (-1.46)
$r^2 = 48.73,\ F = 20.12,\ n = 45$

(5) $\ln(R) = -1.763 + .176\ \ln(P) + .990\ \ln(F) + 1.054\ \ln(Y)$
(3.14) (.98) (3.51)
$r^2 = 43.68,\ F = 10.6,\ n = 45$

In the first three equations which deal with apartment units, the variables are always significant and the signs on the coefficients are robust. All three equations give very similar results as can be seen in Figure C1.1 below. Equation (1) seems to give the best fit and was selected for further work in this study.

For attached and semi-attached units, the regressions results were considerably weaker. This is evident from the r^2 and F values. Functional forms like those in the first three equations were tested, but only the best equations are presented here. A very low t-score prompted the exclusion of the variable P from equation (4).

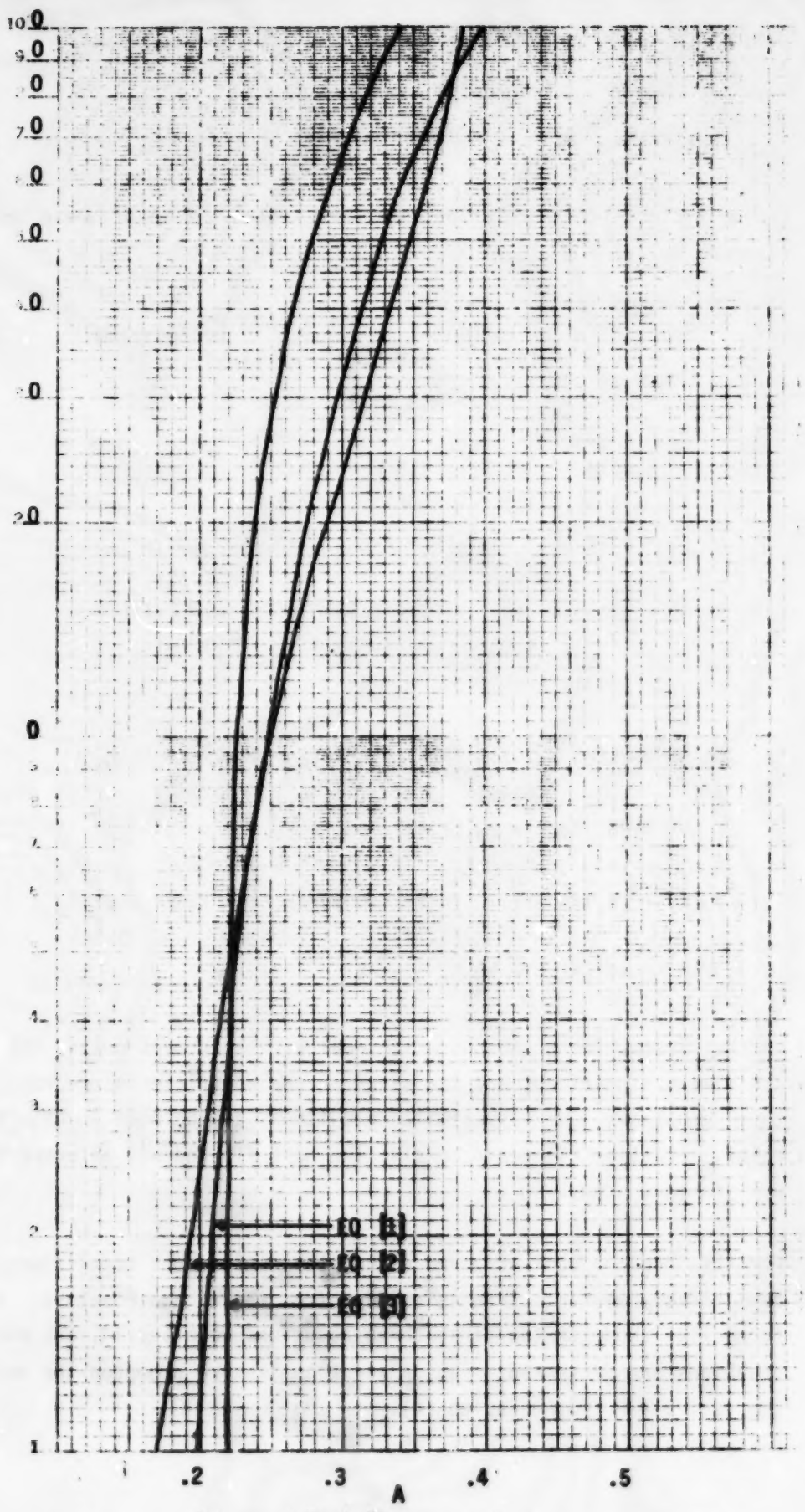

Figure C1.1 Regression Results For A=f(P,Y,F), Y=.2, F=3

The projections in Table C1.2 were made with equations (1), (4) and (5). The proportion of detached units was estimated as a residual once the three values for the other types of units were determined. For these projections, 1976 income levels were used. A range of population projections were available and a single projection of family size was used for all cities. This projection predicted a fall in family size from 3.1 in 1976 to 2.6 by 2001 and a stable size thereafter. Generally, the figures in Table C1.2 foretell a dramatic shift from detached units to semi-detached and apartment units. The assumed fall in family size is a critical factor determining this reallocation.

TABLE C1.2

Projections of the Mix of Dwelling Units

Community	Kitchener/Waterloo				Cambridge				Guelph			Brantford		
Population Forecast	"Low Low"	Low	Med	High	"Low Low"	Low	Med	High	Low	Med	High	Low	Med	High
% of Detached Units														
1976	51	51	51	51	57	57	57	57	55	55	55	61	61	61
2001	35	34	34	33	39	39	39	38	39	38	38	44	44	43
2031	34	33	31	31	38	38	37	37	38	36	34	43	42	41
% Apartments														
1976	34	34	34	34	24	24	24	24	20	30	30	21	21	21
2001	47	47	48	48	36	36	36	36	41	42	42	33	33	33
2031	47	48	50	51	36	36	38	38	42	44	46	34	35	36
% Semi-Detached														
1976	5	5	5	5	6	6	6	6	3	3	3	8	8	8
2001	11	11	11	11	15	15	15	15	11	11	11	16	16	16
2031	11	11	11	10	15	15	14	14	11	10	10	16	16	16
% Attached Units														
1976	11	11	11	11	13	13	13	13	12	12	12	9	9	9
2001	8	8	8	8	11	11	11	11	9	9	9	7	7	7
2031	8	8	8	8	11	11	11	11	9	10	10	7	7	8

APPENDIX D

INDUSTRIAL AND COMMERCIAL WATER TAKINGS

APPENDIX D

INDUSTRIAL AND COMMERCIAL WATER-TAKINGS

Appendix D consists of a set of Grand River sub-basin maps which indicates the location of industrial and commercial water-takings updated to September 1982. These maps are available for viewing and study at selected basin municipality libraries, the Ministry of the Environment regional offices in London and Hamilton, and the Grand River Conservation Authority in Cambridge.

These maps differentiate various sources of permitted water takings (ie. stream takings, wells, or dugout ponds). The information presented is based on detailed data provided by the Ministry of the Environment. These data, compiled relevant to the sub-basins outlined in Figure 2.2, are summarized in Table 6.1. The locations of permitted industrial and commercial water-takings are illustrated in Figures D1.A - D1.L using base maps provided by the Ministry and consequently, sub-basin titles and boundaries vary slightly from those used in the Basin Study. Locations of permitted water-takings are indicated by a permit number which relates to the number of permits located within a particular sub-basin, not the Ministry's file permit number. Detailed information relating to permitted industrial and commercial water-takings is available at the Ministry's regional offices.

APPENDIX E

IRRIGATION WATER TAKINGS
AND RECREATIONAL STORAGE PONDS

APPENDIX E

IRRIGATION WATER-TAKINGS AND RECREATIONAL STORAGE PONDS

Appendix E consists of a set of Grand River sub-basin maps which indicates the location of irrigation water-takings and recreational storage ponds updated to September 1982. These maps are available for viewing and study at selected basin municipality libraries, the Ministry of the Environment regional offices in London and Hamilton, and the Grand River Conservation Authority in Cambridge.

These maps differentiate various sources of permitted water takings (ie. stream takings, wells, or dugout ponds) and specific irrigation use (ie. market garden, tobacco, sod, golf, or recreation). The information presented is based on detailed data provided by the Ministry of the Environment. These data, compiled relevant to the sub-basins outlined in Figure 2.2, are summarized in Table 6.1. The locations of permitted irrigation water-takings and recreational storage ponds are illustrated in Figures E1.A - A1.J using base maps provided by the Ministry and consequently, sub-basin titles and boundaries vary slightly from those used in the Basin Study. Locations of permitted water-takings are indicated by a permit number which relates to the number of permits located within a particular sub-basin, not the Ministry's file permit number. Detailed information relating to permitted irrigation water-takings and recreational storage ponds is available at the Ministry's regional offices.

APPENDIX F

WATER DEMAND PROJECTIONS FOR AGRICULTURAL IRRIGATION 2001 AND 2031

Estimated Water Demand for Irrigation - Scenario 1

Sector	Associated Sub-Basins	Total Area of Sector (acres)	Estimated Area of Soils in Sand/Sandy Loam		Projected Area of Corn (acres)		Other Row Crops (acres)		Projected Area of (acres) Corn		Other		Estimated Area Requiring Irrigation Estimated Water Demand (mg)* Corn		Other	
			Acres	% of Sub Basin	2001	2031	2001	2031	2001	2031	2001	2031	2001	2031	2001	2031
Lower Grand River																
a) Grand River above Lake Belmont	GA0101; GA0102	170,178	3,404	2	14,440	25,495	237	237	289	510	5	5	19.51	34.43	0.29	0.29
b) Grand River above Shand Dam	GA0103	33,098	1,792	5	9,156	14,756	0	0	458	738	0	0	30.92	49.82	0	0
Total		203,276	5,196	2.6	23,596	40,251	237	237	747	1,248	5	5	50.43	84.25	0.29	0.29
Conestogo River																
a) Conestogo River above Conestogo Lake	GA0601	68,436	691	1	10,391	18,100	0	0	104	181	0	0	7.02	12.22	0	0
b) Conestogo River above Conestogo Dam	GA0602	71,208	666	1	21,430	37,334	0	0	214	373	0	0	14.45	25.18	0	0
c) Conestogo River below Conestogo Dam	GA0603; GA0604	65,608	1,101	2	27,679	33,350	240	240	550	667	5	5	37.13	45.02	0.29	0.29
Total		205,252	2,458	1.2	59,500	88,784	240	240	868	1,221	5	5	58.60	82.42	0.29	0.29
Middle Grand River																
a) Grand River above West Montrose	GA0104	90,777	3,360	3.7	46,041	53,152	0	0	1,842	2,126	0	0	124.34	143.51	0	0
b) Canagagigue Creek	GA0105; GA0106	26,980	1,048	3.9	11,268	11,268	0	0	451	451	0	0	30.44	30.44	0	0
c) Speed River above Guelph	GA0401; GA0402	68,797	11,167	16.0	31,653	31,653	203	203	5,032	5,032	33	33	339.66	339.66	1.88	1.88
d) Speed River below Guelph	GA0403; GA0404; GA0405; GA0406; GA0407; GA0408	56,753	3,507	6.0	13,204	13,204	205	205	792	792	12	12	53.46	53.46	0.68	0.68
e) Eramosa River above Guelph	GA05	65,467	1,715	3.0	12,459	15,929	0	0	374	478	0	0	25.25	32.27	0	0
f) Galt Creek	GA0301; GA0302; GA0303; GA0304	26,517	160	0.7	3,248	3,305	0	0	23	23	0	0	1.55	1.55	0	0
g) Grand River above Cambridge	GA0107; GA0108; GA0109; GA0110	125,903	Insufficient Data		34,012	34,012	622	622	-	-	-	-	-	-	-	-
Total		458,804	20,978	4.6	151,685	162,413	1,030	1,030	8,514	8,902	45	45	574.7	600.89	2.56	2.56
Paris	GA0111	23,794	840	3.0	6,889	6,889	0	0	207	207	0	0	13.97	13.97	0	0
Nith River	GA0201; GA0202; GA0203; GA0204; GA0205; GA0206; GA0207; GA0208; GA0209; GA0210	283,134	20,433	7.3	112,481	128,144	2,045	2,045	7,867	8,970	143	143	531.50	605.48	8.15	8.15
Whitemans Creek	GA0501; GA0502	100,662	12,749	12.7	44,332	44,332	5,528	5,528	5,320	5,320	442	442	359.10	359.10	25.19	25.19
Lower Grand River																
a) Fairchild and Big Creek	GA04; GA03	145,249	973	0.7	45,080	45,080	2,040	2,040	316	316	14	14	21.33	21.33	0.80	0.80
b) McKenzie Creek	GA0301	50,134	2,919	5.8	13,232	14,007	2,423	2,423	794	840	121	121	53.60	56.70	6.90	6.90
c) Boston Creek	GA0302	57,015	1,101	1.9	19,548	25,523	1,842	1,842	391	510	29	29	26.39	34.43	1.65	1.65
d) Grand River below Brantford	GA0101; GA0102; GA0103	194,826	6,336	3.3	48,733	56,234	2,537	2,537	1,462	1,627	51	51	98.69	109.82	2.91	2.91
Total		447,224	11,329	2.5	126,593	139,844	8,842	8,842	2,963	3,293	215	215	200.01	222.28	12.26	12.26
Total Watershed		1,722,076	73,983	4.3	524,874	609,657	17,522	17,522	26,466	29,161	855	855	1,788.31	1,968.39	48.74	48.74

*Calculated for a 92 day period from June 1 to August 31.

TABLE F1.2

Estimated Water Demand for Irrigation - Scenario 2

Sector	Associated Sub-Basins	Total Area of Sector (acres)	Estimated Area of Soils in Sand/Sandy Loam		Projected Area of Corn (acres)		Projected Area of Other Row Crops (acres)		Estimated Area Requiring Irrigation (acres)				Estimated Water Demand (mg)*			
			Acres	% of Sub Basin	2001	2031	2001	2031	Corn 2001	Corn 2031	Other 2001	Other 2031	Corn 2001	Corn 2031	Other 2001	Other 2031
Upper Grand River																
a) Grand River above Lake Belwood	GR0101; GR0102	170,176	3,404	2	14,440	25,495	237	237	289	510	5	5	19.51	34.43	0.29	0.29
b) Grand River above Shand Dam	GR0103	33,098	1,792	5	9,154	12,089	NIL	NIL	458	605	NIL	NIL	30.92	40.84	NIL	NIL
Total		203,274	5,196	2.6	23,594	37,584	237	237	747	1,115	5	5	50.43	75.27	0.29	0.29
Conestogo River																
a) Conestogo River above Conestogo Lake	GR0801	69,436	691	1	10,391	18,100	NIL	NIL	104	181	NIL	NIL	7.02	12.22	NIL	NIL
b) Conestogo River above Conestogo Dam	GR0802	71,208	666	1	21,630	37,334	NIL	NIL	216	373	NIL	NIL	14.65	25.18	NIL	NIL
c) Conestogo River below Conestogo Dam	GR0803; GR0804	65,608	1,101	2	10,845	10,845	240	240	217	217	5	5	14.65	14.65	0.29	0.29
Total		205,252	2,458	1.2	42,666	66,279	240	240	535	771	5	5	36.12	52.05	0.29	0.29
Middle Grand River																
a) Grand River above West Montrose	GR09A	90,777	3,360	3.7	41,605	41,605	NIL	NIL	1,668	1,668	NIL	NIL	112.32	112.32	NIL	NIL
b) Canagagigue Creek	GR0905; GR0906	26,580	1,049	3.9	9,203	9,203	NIL	NIL	368	368	NIL	NIL	24.84	24.84	NIL	NIL
c) Speed River above Guelph	GR0401; GR0402	69,797	11,187	16.0	25,184	25,184	203	203	4,029	4,029	33	33	271.36	271.36	1.84	1.84
d) Speed River below Guelph	GR0403; GR0404; GR0405; GR0406; GR0407; GR0408	56,733	3,407	6.0	11,085	11,085	205	205	665	665	12	12	44.89	44.89	0.68	0.68
e) Eramosa River above Guelph	GR09	45,467	1,715	3.0	12,939	12,933	NIL	NIL	324	324	NIL	NIL	25.25	25.19	0	0
f) Galt Creek	GR0301; GR0302; GR0303; GR0304	24,517	160	0.7	3,142	3,142	NIL	NIL	22	22	NIL	NIL	1.69	1.69	0	0
g) Grand River above Cambridge	GR10F; GR10G; GR10P; GR110	125,903	Insufficient Data		27,627	27,627	622	622	-	-	-	-	-	-	-	-
Total		458,804	20,978	4.6	130,305	130,279	1,030	1,030	7,122	7,136	45	45	480.75	481.69	2.56	2.56
Paris	GR111	23,754	640	3.0	5,997	5,997	NIL	NIL	180	180	NIL	NIL	12.15	12.15	0	0
Nith River	GR0201; GR0202; GR0203; GR0204; GR0205; GR0206; GR0207; GR0208; GR0209; GR210	283,104	20,633	7.3	97,993	112,513	2,046	2,046	6,855	7,876	143	143	462.71	531.68	8.15	8.15
Whiteman Creek	GR0501; GR0502	100,662	12,749	12.7	37,178	37,178	5,528	5,528	4,461	4,461	442	442	301.12	301.12	25.19	25.19
Lower Grand River																
a) Fairchild and Big Creek	GR04; GR03	145,249	973	0.7	38,189	38,189	2,040	2,040	267	267	14	14	18.02	18.02	0.80	0.80
b) McKenzie Creek	GR0301	50,134	2,919	5.8	13,205	13,205	2,423	2,423	660	660	121	121	44.55	44.55	6.90	6.90
c) Boston Creek	GR0302	57,015	1,101	1.9	19,548	24,789	1,842	1,842	391	496	29	29	26.39	33.48	1.65	1.65
d) Grand River below Brantford	GR0101; GR0102; GR0103	194,826	6,336	3.3	48,733	48,733	2,537	2,537	1,462	1,462	51	51	98.69	98.69	2.91	2.91
Total		447,224	11,329	2.5	119,675	124,916	8,842	8,842	2,780	2,885	215	215	187.65	194.74	12.26	12.26
Total Watershed		1,722,076	73,943	4.3	457,348	515,250	17,922	17,922	22,680	24,424	855	855	1,530.99	1,648.65	48.74	48.74

*Calculated for a 92 day period from June 1 to August 31.

TABLE F1.3

Estimated Water Demand for Irrigation - Scenario 3

Sector	Aggregated Sub-Basins	Total Area of Sector (acres)	Estimated Area of Soils in Sand/Sandy Loam		Projected Area of Corn (acres)		Projected Area of Other Row Crops (acres)		Estimated Area Requiring Irrigation (acres)				Estimated Water Demand (mg)*			
									Corn		Other		Corn		Other	
			Acres	% of Sub Basin	2001	2031	2001	2031	2001	2031	2001	2031	2001	2031	2001	2031
Upper Grand River																
a) Grand River above Lake Belwood	GRD101; GRD102	170,178	3,404	2	14,440	25,495	237	237	289	510	5	5	19.51	34.43	0.29	0.29
b) Grand River above Shand Dam	GRD103	33,098	1,792	5	9,156	14,756	NIL	NIL	458	738	NIL	NIL	30.92	49.82	NIL	NIL
Total		203,276	5,196	2.6	23,596	40,251	237	237	747	1,248	5	5	50.43	84.25	0.29	0.29
Conestogo River																
a) Conestogo River above Conestogo Lake	GRD201	68,436	691	1	10,391	18,100	NIL	NIL	104	181	NIL	NIL	7.02	12.22	NIL	NIL
b) Conestogo River above Conestogo Dam	GRD202	71,208	666	1	21,430	37,334	NIL	NIL	214	373	NIL	NIL	14.45	25.18	NIL	NIL
c) Conestogo River below Conestogo Dam	GRD203; GRD204	65,688	1,101	2	27,479	33,350	240	240	550	667	5	5	37.13	45.02	0.29	0.29
Total		205,232	2,458	1.2	59,300	88,784	240	240	868	1,221	5	5	58.60	82.42	0.29	0.29
Middle Grand River																
a) Grand River above West Montrose	GRD304	90,777	3,360	3.7	36,428	53,152	NIL	NIL	1,457	2,126	NIL	NIL	98.35	143.51	NIL	NIL
b) Canagagigue Creek	GRD305; GRD306	26,980	1,049	3.9	7,596	10,628	NIL	NIL	301	425	NIL	NIL	20.32	28.69	NIL	NIL
c) Speed River above Guelph	GRD401; GRD402	68,797	11,187	16.0	31,653	31,653	203	203	5,032	5,032	33	33	339.66	339.66	1.88	1.88
d) Speed River below Guelph	GRD403; GRD404; GRD405; GRD406; GRD407; GRD408	56,759	3,507	6.0	6,798	6,798	205	205	407	407	12	12	27.47	27.47	0.68	0.68
e) Eramosa River above Guelph	GRD5	65,467	1,715	3.0	12,459	15,929	NIL	NIL	374	478	NIL	NIL	25.25	32.27	NIL	NIL
f) Galt Creek	GRD501; GRD502; GRD503; GRD504	24,517	160	0.7	3,248	3,248	NIL	NIL	23	23	NIL	NIL	1.55	1.55	NIL	NIL
g) Grand River above Cambridge	GRD107; GRD108; GRD109; GRD110	125,903	Insufficient Data		21,539	21,539	622	622	-	-	-	-	-	-	-	-
Total		458,604	20,978	4.6	119,431	142,719	1,030	1,030	7,586	8,491	45	45	512.60	573.15	2.56	2.56
Paris	GRD111	23,754	690	3.0	6,889	6,889	NIL	NIL	207	207	NIL	NIL	13.97	13.97	NIL	NIL
Nith River	GRD601; GRD602; GRD603; GRD604; GRD605; GRD606; GRD607; GRD608; GRD609; GRD610	283,104	20,633	7.3	93,907	114,087	2,045	2,045	6,573	7,985	143	143	443.68	538.99	8.15	8.15
Whitemans Creek	GRD501; GRD502	100,642	12,749	12.7	44,329	44,329	5,528	5,528	5,319	5,319	642	642	359.03	359.03	25.19	25.19
Lower Grand River																
a) Fairchild and Big Creek	GRD4; GRD3	145,249	973	0.7	16,104	18,154	2,040	2,040	258	267	14	14	17.42	18.02	.80	.80
b) McKenzie Creek	GRD801	50,134	2,919	5.8	13,232	14,007	2,423	2,423	662	700	121	121	44.69	47.25	6.90	6.90
c) Boston Creek	GRD802	57,015	1,101	1.9	10,908	15,868	1,842	1,842	218	317	29	29	14.72	21.40	1.65	1.65
d) Grand River below Brantford	GRD101; GRD102; GRD103	194,826	6,336	3.3	48,824	56,234	2,537	2,537	1,465	1,627	51	51	98.89	109.82	2.91	2.91
Total		447,224	11,329	2.5	109,068	122,263	8,842	8,842	2,603	2,911	215	215	175.72	196.49	12.26	12.26
Total Watershed		1,722,076	73,983	4.3	457,318	559,310	17,522	17,522	23,911	27,382	885	885	1,614.03	1,848.30	48.74	48.74

*Calculated for a 92 day period from June 1 to August 31.

TABLE F1.4

Estimated Water Demand for Irrigation - Scenario A

Sector	Associated Sub-Basins	Total Area of Sector (acres)	Estimated Area of Soils in Sand/Sandy Loam		Projected Area of Corn (acres)		Projected Area of Other Row Crops (acres)		Estimated Area Requiring Irrigation (acres)				Estimated Water Demand (mg)*			
			Acres	% of Sub Basin	2001	2031	2001	2031	Corn 2001	Corn 2031	Other 2001	Other 2031	Corn 2001	Corn 2031	Other 2001	Other 2031
Upper Grand River																
a) Grand River above Lake Belwood	GA0101; GA0102	170,178	3,404	2	5,940	5,940	237	237	119	119	5	5	8.03	8.03	0.29	0.29
b) Grand River above Shand Dam	GA0103	33,098	1,792	5	4,290	4,290	NIL	NIL	215	215	NIL	NIL	14.51	14.51	NIL	NIL
Total		203,276	5,196	2.6	10,230	10,230	237	237	334	334	5	5	22.54	22.54	0.29	0.29
Conestogo River																
a) Conestogo River above Conestogo Lake	GA0601	68,436	691	1	3,530	3,530	NIL	NIL	35.3	35.3	NIL	NIL	2.38	2.38	NIL	NIL
b) Conestogo River above Conestogo Dam	GA0602	71,208	666	1	11,468	11,468	NIL	NIL	115	115	NIL	NIL	7.76	7.76	NIL	NIL
c) Conestogo River below Conestogo Dam	GA0603; GA0604	65,608	1,101	2	14,850	14,850	240	240	297	297	5	5	20.05	20.05	0.29	0.29
Total		205,252	2,458	1.2	29,848	29,848	240	240	447.3	447.3	5	5	30.19	30.19	0.29	0.29
Middle Grand River																
a) Grand River above West Montrose	GA0104	90,777	3,380	3.7	16,087	16,087	NIL	NIL	653	653	NIL	NIL	43.60	43.60	NIL	NIL
b) Canagagigue Creek	GA0105; GA0106	26,580	1,049	3.9	4,054	4,054	NIL	NIL	194	194	NIL	NIL	13.10	13.10	NIL	NIL
c) Speed River above Guelph	GA0401; GA0402	68,797	11,187	16.0	15,381	15,381	203	203	2,461	2,461	33	33	166.12	166.12	1.88	1.88
d) Speed River below Guelph	GA0403; GA0404; GA0405; GA0406; GA0407; GA0408	56,753	3,507	6.0	6,788	6,788	205	205	407	407	12	12	27.47	24.47	0.68	0.68
e) Eramosa River above Guelph	GA05	65,467	1,715	3.0	3,236	3,236	NIL	NIL	97.5	97.5	NIL	NIL	6.55	6.55	NIL	NIL
f) Galt Creek	GA0301; GA0302; GA0303; GA0304	29,517	180	0.7	1,067	1,067	NIL	NIL	7.5	7.5	NIL	NIL	.51	.51	NIL	NIL
g) Grand River above Cambridge	GA0107; GA0108; GA0109; GA0110	125,903	Insufficient Data		21,539	21,539	622	622								
Total		458,804	20,978	4.6	68,952	68,952	1,030	1,030	3,810	3,810	45	45	34.53	34.53	2.56	2.56
Paris	GA0111	23,754	840	3.0	5,518	5,518	NIL	NIL	166	166	NIL	NIL	11.21	11.21	NIL	NIL
Nith River	GA0201; GA0202; GA0203; GA0204; GA0205; GA0206; GA0207; GA0208; GA0209; GA0210	283,104	20,633	7.3	64,194	64,194	2,045	2,045	4,488	4,488	143	143	302.54	302.54	8.15	8.15
Whitemans Creek	GA0501; GA0502	100,662	12,769	12.7	26,231	26,231	5,528	5,528	3,148	3,148	442	442	212.69	212.69	25.19	25.19
Lower Grand River																
a) Fairchild and Big Creek	GA04; GA03	145,248	973	0.7	28,232	28,232	2,040	2,040	198	198	14	14	13.37	13.37	.80	.80
b) McKenzie Creek	GA0201	50,134	2,919	5.8	7,328	7,328	2,423	2,423	366	366	121	121	24.71	24.71	6.90	6.90
c) Boston Creek	GA0202	57,015	1,101	1.9	5,054	5,054	1,442	1,442	117	117	29	29	7.90	7.90	1.65	1.65
d) Grand River below Brantford	GA0101; GA0102; GA0103	194,826	6,336	3.3	17,730	17,730	2,337	2,337	532	532	51	51	35.91	35.91	2.91	2.91
Total		447,224	11,329	2.5	58,342	58,342	8,842	8,842	1,213	1,213	215	215	81.89	81.89	12.26	12.26
Total Watershed		1,722,076	73,983	4.3	264,055	264,055	17,522	17,522	13,406	13,406	885	885	695.79	695.79	48.74	48.74

*Calculated for a 92 day period from June 1 to August 31.

APPENDIX G

LIVESTOCK WATER DEMAND, 1976, 2001 AND 2031

TABLE G1.1

Livestock Water Demand in the Grand River Watershed (1976)

Sub-Basin	No. of Milk Cows	Estimated Water Demand Milk Cows (gpd)	No. of Other Cattle	Estimated Water Demand Other Cattle (gpd)	No. of Pigs	Estimated Water Demand Pigs (gpd)	No. of Sheep	Estimated Water Demand Sheep (gpd)	Total Number of Livestock	Total Estimated Water Demand All Livestock (gpd)
Lower Grand River	19,725	789,000	25,860	387,900	41,681	83,362	2,418	4,836	89,684	1,265,098
Whiteman Creek	6,149	245,960	10,445	156,675	20,438	40,876	145	290	37,177	443,801
Nith River	23,059	922,360	52,142	782,130	92,034	184,068	1,462	2,924	168,697	1,891,482
Paris	1,002	40,080	3,555	53,325	2,299	4,598	167	334	7,023	98,337
Middle Grand River	14,421	576,840	51,177	767,655	95,463	190,926	5,220	10,440	166,281	1,545,861
Conestogo River	19,815	792,600	48,437	726,555	121,017	242,034	775	1,550	190,044	1,762,739
Upper Grand River	5,803	232,120	27,594	413,910	20,755	41,510	1,586	3,172	55,738	690,712
Totals	89,974	3,598,960	219,210	3,288,150	393,687	787,374	11,743	23,545	714,644	7,698,030

TABLE G1.2

Livestock Water Demand in the Grand River Watershed (2001)

Sub-Basin	No. of Milk Cows	Estimated Water Demand Milk Cows (gpd)	No. of Other Cattle	Estimated Water Demand Other Cattle (gpd)	No. of Pigs	Estimated Water Demand Pigs (gpd)	No. of Sheep	Estimated Water Demand Sheep (gpd)	Total Number of Livestock	Total Estimated Water Demand All Livestock (gpd)
Lower Grand River	5,705	228,200	7,480	112,200	12,056	24,112	699	1,398	25,940	365,910
Whiteman Creek	6,265	250,600	10,642	159,630	20,820	41,640	145	290	37,872	452,160
Nith River	32,434	1,297,360	73,340	1,100,100	124,440	248,880	1,992	3,984	232,206	2,650,324
Paris	1,006	40,240	3,572	53,580	2,520	5,040	167	334	7,265	99,194
Middle Grand River	26,466	1,058,640	93,921	1,408,815	171,975	343,950	8,340	16,680	300,702	2,828,085
Conestogo River	22,180	887,200	54,218	813,270	139,755	279,510	800	1,600	216,953	1,981,580
Upper Grand River	6,301	252,040	29,964	449,460	23,651	47,302	2,102	4,204	62,018	753,006
Totals	100,357	4,014,280	273,137	4,097,055	495,217	990,434	14,245	28,490	882,956	9,130,259

TABLE G1.3

Livestock Water Demand in the Grand River Watershed (2031)

Sub-Basin	No. of Milk Cows	Estimated Water Demand Milk Cows (gpd)	No. of Other Cattle	Estimated Water Demand Other Cattle (gpd)	No. of Pigs	Estimated Water Demand Pigs (gpd)	No. of Sheep	Estimated Water Demand Sheep (gpd)	Total Number of Livestock	Total Estimated Water Demand All Livestock (gpd)
Lower Grand River	5,705	228,200	7,480	112,200	12,056	24,112	699	1,398	25,940	365,910
Whiteman Creek	4,890	195,600	8,306	124,590	16,245	32,490	112	224	29,553	352,904
Nith River	39,507	1,580,280	89,334	1,340,010	75,795	151,590	2,424	4,848	207,060	3,076,728
Paris	907	36,280	3,219	48,285	2,267	4,534	157	314	6,550	89,413
Middle Grand River	34,787	1,391,480	123,451	1,851,765	226,050	452,100	10,960	21,920	395,248	3,717,265
Conestogo River	28,729	1,149,160	70,228	1,053,420	181,020	362,040	1,036	2,072	281,013	2,566,692
Upper Grand River	6,301	252,040	29,964	449,460	23,651	47,302	2,102	4,204	62,018	753,006
Totals	120,826	4,833,040	331,982	4,979,730	537,084	1,074,168	17,490	34,980	1,007,382	10,921,918